ELECTRICAL INSTALLATIONS OF THE UNITED STATES NAVY

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A MANUAL OF THE LATEST APPROVED MATERIAL, INCLUDING ITS USE, OPERATION, INSPECTION, CARE AND MANAGEMENT, AND METHOD OF INSTALLATION ON BOARD SHIP

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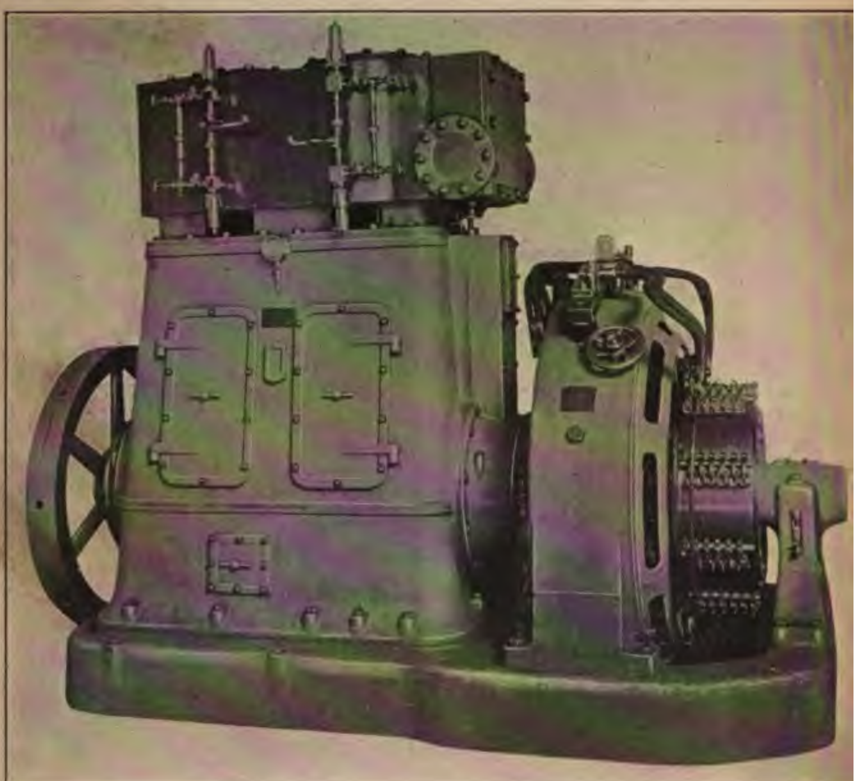

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GENERAL ELECTRIC COMPANY.

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CHAPTER I.

INCANDESCENT LAMPS.

General Considerations of Naval Types.

The incandescent lamp has at least two great advantages over almost all other sources of light: the first is that it can be turned into any position which will best utilize its light; the second is that the distribution of the luminous intensity of the lamp can be varied within wide limits by the mere shaping of its filament. It is an interesting fact that, while much has been done towards improvements in details, the incandescent electric lamp, as invented twenty-five years ago, is still much the same as the original invention in general appearance and construction. The lamp is essentially a filament of carbon heated to incandescence by the passage of an electric current, the filament being enclosed in an exhausted transparent receptacle to prevent that combustion of its material which would immediately ensue if the material were subjected to high temperature in the presence of oxygen; hence oxygen must be rigorously eliminated and this can be accomplished by exhaust-

ing the receptacle by some form of air pump and removing residual oxygen by chemical combination.

The availability of a material for filaments depends upon two qualifications: first, it must be capable of attaining extremely high temperatures without fusing or volatilizing, and upon this qualification depends the efficiency of the material as an illuminant; second, it must be a conductor of electricity.

These two conditions apparently exclude all substances except carbon and the metals with the exception, perhaps, of certain oxides, as a comparison of incandescent lamps, notably those used in the Nernst and Osmium lamps; the oxide types are, however, too fragile for ship use. Practically the conditions narrow the usual selection to carbon, since, as all substances are fused and volatilized at or below the temperature of the electric arc, the arc must represent the best possible source of artificial illumination. The temperature of the incandescent filament is lower than that of the arc and therefore the illumination of the arc must be the superior; still, the temperature of the filament at incandescence is probably as high as 1800° C., a temperature higher than the fusing point of platinum. Carbon, then, not only fulfills the necessary conditions but is at the same time cheap and abundant and possesses the property, unlike metals, of decreasing its resistance with rise of temperature, the resistance of a filament at incandescence being only about half its resistance when cold.

The problem of the filament is to obtain a homogeneous carbon whose specific resistance will be the same in all parts that the filament may not tend to burn away in one section more than in another; and to construct a dense carbon which will not readily disintegrate and blacken with carbon dust the interior surface of the exhausted receptacle, commonly called the bulb; these conditions satisfied, the resistance necessary to the different filaments are readily adjustable by length and cross-sectional area.

The question of selection of a desirable incandescent lamp, apart from those entering into methods of construction, is dependent upon the following considerations:

The Source of Illumination.—This has been determined by experiment to be usually a carbon filament heated to incandescence in an exhausted bulb whose vacuous space is devoid of oxygen.

The Intensity of Illumination.—The number of lumens

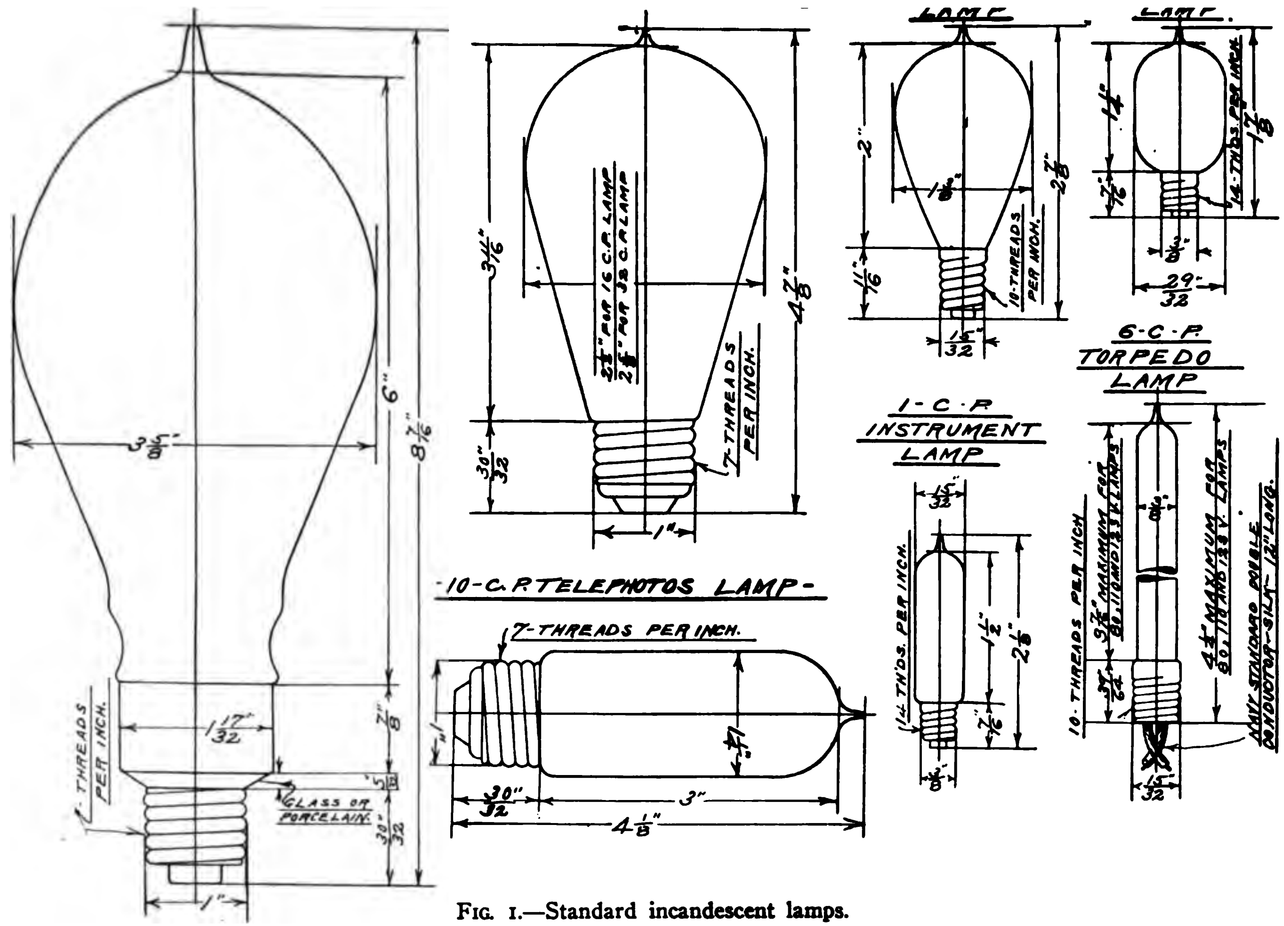

FIG. 1.—Standard incandescent lamps.

emitted from a source of light are measured by reference to the standard candle and are expressed as so many candle-power for the particular source. Types of incandescent lamps are therefore separated in this consideration by the candle-power emissivity for which they are designed, or "rated." Ordinarily comparisons are made on the 16-candle-power lamp which is regarded as the universal practical standard.

In the navy the following candle-powers are used:

Regular Lamps.

16 candle-power.
32 candle-power.
150 candle-power (diving lamp).
5 candle-power (instrument lamp).

Instrument and Special Lamps.

10 candle-power (telephotos lamp).
2 candle-power (instrument lamp).
1 candle-power (instrument lamp).
6 candle-power (torpedo lamp).

All of these classes have their bulbs of clear and transparent glass. In the case of the 16-candle-power lamp a frosted type is allowed, which gives a diminished candle-power after frosting, but the light emitted is softer for reading or for desk use. The different types are shown in outline in Fig. 1. The total number of lamps allowed each ship is on the basis of four for each outlet.

The 16-candle-power lamp is the working lamp for general lighting throughout the ship.

The 32-candle-power lamp is allowed for signals, running lights, truck lights, etc., and can be used to advantage to increase the light in dimly-lighted magazines and shell-rooms where the 16 candle-power originally installed is insufficient. The allowance furnished a ship, however, restricts this type of lamp to navigational and signal use.

The 150-candle-power lamp is supplied for diving use.

The 5-candle-power instrument lamp is for illuminating the indications of "lamp indicating instruments," such as the Helm Angle Indicator, Helm Telegraph, Engine Telegraph, and for lighting binnacles and mechanical telegraphs.

The 6-candle-power torpedo lamp is mounted on the end of a rod for examining the interior of automobile torpedoes and is

made long and narrow that it may be readily inserted in the small orifices in the side of the torpedo.

The 10-candle-power telephotos lamp is an especial form of lamp for the telephotos type of (red and white) lantern of the night signalling lanterns. The lanterns of night signalling sets of the General Electric Company's manufacture and some telephotos lanterns are supplied with a single 32-candle-power standard lamp in each half of the lantern; the usual telephotos lantern requires four 10-candle-power lamps in the red half and three in the white half.

The 2-candle-power lamp is for illuminating the dials of the Fiske type of instruments, and the 1-candle-power for the same purpose in the Cory instruments, no greater intensity being necessary in either case. A 10-candle-power regular lamp is sometimes met with but its intended installation in engine- and fire-rooms effects no good economy when compared with the loss of illumination in those locations.

Lamp Voltage.—The voltage which is to be maintained at the terminals of a given lamp is that voltage which will produce the rated candle-power, at the resistance of the filament, and is restricted by the fact that the life of the filament decreases as the standard voltage is increased, that is, a lower voltage lamp will usually be the longer lived.

The voltage of lamps, except the 1 candle-power (which has an especial voltage of 10 volts for convenience of construction), primarily depends upon the terminal voltage of the dynamos which are to supply the energy. Formerly dynamos have been prescribed for a terminal voltage of 80 volts and the voltage of lamps has been prescribed at 80 volts, mean, between the limits of 78 volts and 82 volts; the variation in limits being allowed in order that a larger number of lamps may be obtained from any manufactured lot than would be practicable if the normal (80 volts) was rigidly prescribed and fixed.

Upon the adoption of the 125-volt dynamos, and for use with the 110-volt machines installed in auxiliaries, both 123-volt and 110-volt lamps have come into use, the 123-volt being now the standard for 125-volt installations. In order to obtain a range of selection, variations in limits are also prescribed for the 123-volt and 110-volt lamps as in the case of those for 80 volts.

A condition which affects the selection of voltage is the ques-

tion of commercial supply and demand, that is, the ability of the manufacturers to fill an order in view of other contracts. For a 125-volt installation a lamp of any voltage between 110 and 124 volts may be used; all types are commonly used by commercial companies at different distances from the power-house to accommodate the lamp to the loss of potential due to distance, or for saving in cost of copper by reason of available reduction in wire size.

The average ratio of supply to demand for 110-volt lamps in the market is as 6 to 9; lamps at this voltage are therefore difficult to obtain, and the case is approximately the same for other voltages up to 119 volts. It is not advantageous, considering the short distances of runs in ships, to endeavor to reduce wire size by using a variety of voltages, and an allowance of 3 per cent drop renders a 123-volt lamp available at all ship distances and necessitates but one type. In the variations of a supply furnished a ship, occasioned by the limits in acceptance, those lamps having voltages lower than 123 are placed at the farther end of lines of wiring, and those nearer to or above 123 volts, in the vicinity of the dynamo-rooms.

Lamp Efficiency.—The economic performance of a lamp is measured by the number of units of energy which the lamp consumes, and this energy is electrically measured by the number of watts required by the lamp, as determined by the product of the current passing through the filament and the voltage at its terminals; this product is called the *total watts*. The total watts divided by the candle-power of the lamp, or the number of watts per candle-power (w. p. c.), is taken as the measure of the lamp's efficiency.

Experiment has determined three practicable efficiencies: 3.1, 3.5, and 4.0 w. p. c. As explained under the subject of voltage, to obtain a range in selection, these efficiencies are prescribed between limits: 2.9 to 3.3 w. p. c., 3.3 to 3.7 w. p. c., and 3.6 to 4.0 w. p. c.

A "high" efficiency of 3.1 w. p. c. will consume the least electric energy for a given lamp of given candle-power, and will give the most brilliant light as compared with lamps of the same candle-power at lower efficiencies, that is, the light will be whitest. The condition obtains only because the lamp at 3.1 w. p. c. is at the highest temperature. In reality no lamp can be said to be of or

have a greater or less efficiency than another: one lamp may be burned, or "run," at a greater efficiency, but it possesses no greater efficiency in itself for the reason that any other lamp can be run at an efficiency just as great; and, further, any lamp can be run at any desired efficiency, approaching in its intensity the electric arc, dependent only upon the temperature, the limiting efficiency being that necessary to the instantaneous destruction of the filament.

Hence, a higher efficiency means a higher state of temperature of the filament; it also means that the filament will burn out more quickly and have a short life. The filament of lamps at an efficiency of 3.1 w. p. c. have the comparatively short life of about 400 hours, and are desirable for those uses alone where extended life is not a consideration as compared with brilliancy, or where a brilliant light is required for but a short time, or intermittently, as in the case of the 150 c. p. diving lamp.

As a life of 1000 hours and above is usually desired and expected, a low efficiency is prescribed for general use; that of the 80-volt lamps heretofore in use is 3.6 to 4 w. p. c., giving long service but showing a yellowish light as compared with the commercial lamp of 3.5 w. p. c. The present standard efficiency is 3.5 w. p. c., between the limits of 3.3 and 3.7 w. p. c., and applies to all classes of lamps except the 150 c. p. diving lamp, whose efficiency is 3.1 w. p. c.

The shorter life of a lamp at high efficiency is taken advantage of in testing the life of lamps from the great saving of time. Though a lamp be *designed* for an efficiency of 3.5 or 3.8 it can be made to burn at any other efficiency by merely altering the voltage, *but it will give a different candle-power from that of the design;* for example, a lamp which is producing 16 candle-power at 80 volts is under life test and it is desired to burn it at 3.1 w. p. c. instead of at the 3.5 of the design; it is only necessary to raise the voltage at the lamp terminals to 82.4 volts, and the efficiency will be 3.1; but the lamp will produce *nineteen candle-power* at the new voltage instead of *sixteen,* and *will consume more electrical energy* than if burned at 3.5 w. p. c.

In addition to changing the efficiency, and farther decrease the time necessary for the life test, it is the custom to burn the test lamp only during its "useful life," or that number of hours in

which its candle-power shall have been decreased to 80 per cent of the rated candle-power.

[Note 1.—The high efficiency of the Nernst lamp in particular has of late turned the attention of lamp manufacturers to metal filaments, from which high efficiencies and consequent economy in energy, are readily derivable; the life of the lamp is about 800 hours. One type has a filament made from the metal tantalum which is, however, brittle and has not met with success in alternating current work; the latest development is a tungsten filament, giving the high efficiency of 1.0 w. p. c.; the saving of energy, economy, of this type of filament over the usual carbon filament type is therefore 71 per cent. The type has not as yet been extensively introduced, and it will probably be many years before the carbon filament lamp is importantly supplanted.]

The Type of Bulb.—The type of bulb is a question of dimension for filament area and for the intended use; the commercial "straight side," or "parachute" bulb is the approved standard.

The Type of Base.—The Edison screw base is in such general use and is so well adapted for securely holding a lamp in place that it has been the permanent standard.

Lamp Manufacture.

The Filament.—The original compound is a pyroxylin made from cotton. The steps of reduction to cellulose vary with different manufacturers, but the main reactions are as follows: The pyroxylin is dissolved by hot concentrated 40 per cent zinc chloride forming a syrupy mixture from which a hydrated cellulose zinc-oxide is precipitated by alcohol. The zinc is freed by hydrochloric acid and washing. The pyroxylin is reduced to cellulose by ammonium sulphide. The resulting compound is a heavy, brownish or amber-colored liquid known as "tamadine," and of the consistency of heavy molasses.

The liquid is put in an inverted bottomless jar, over which is fitted a cap for application of a light air pressure; the neck of the jar is fitted with a pipette nozzle, the diameter varying for the diameter of the filament to be produced. The liquid oozing through the nozzle passes in a thread to a "tub" placed in a slowly-revolving jar which is filled with alcohol to harden it. The tubs undergo several washings to remove the adhering zinc chloride; acidulated washes are sometimes used to remove any stickiness of the surface. In this state the thread becomes a milky-white cord resembling, and a little thicker than, boiled vermicelli.

The cord is thoroughly dried on the surface of a slowly-revolving drum, which is heated internally by gas or steam; drying to a tough, flexible, lustrous thread resembling a white horse hair. In this state it is wound about the posts of a former, or mandrel, having a large and small post; turns are taken around the larger post before crossing to the other in accordance with the number of turns, or spirals, desired in the finished filament. The spirals on the mandrels are slightly baked in an oven to ensure temporary retention of form, and are then cut at the smaller post and taken off the mandrel.

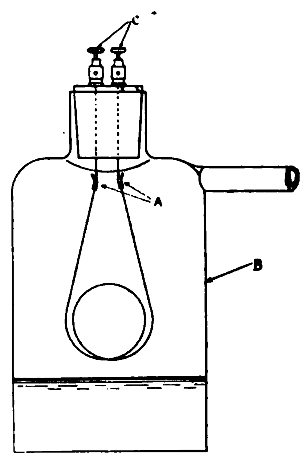

FIG. 2.—Bottle for flashing or treating.

The filaments are then packed in metal boxes filled with peat and brought to a red heat in an oven; this process gives all the shrinkage that will result in carbonizing; at this stage the filament is not yet a conductor of electricity.

The filaments, now of a black color, are packed with a refractory material in plumbago crucibles and carbonized, retaining the formed shape permanently; they are separated carefully and the ends trimmed to the finished length.

The manufacture of the filament thus far assures neither homogeneity throughout nor the appropriate resistance; both are accomplished by the following ingenious process, known as "treating" or "flashing":

The filament is connected by clips (*A*, Fig. 2) in the air-tight cork of a bottle *B*, which contains a volatile hydrocarbon such as

gasoline, benzine, etc. The clips are metallically connected with the binding posts, *C*, to which wires from a source of electricity at proper voltage are connected through a clutched switch and an ammeter (not shown). When the switch is closed the terminals, *C*, are at a slightly higher potential difference than that at which the lamp is to be used. The bottle is first exhausted, the switch is closed, and the filament (within the bottle) becomes incandescent. The heat decomposes the vapor emitted by the hydrocarbon and deposits carbon on the filament; those sections of the filament which have the greatest resistance (or which are of least diameter) will heat most and receive the greatest deposit of carbon, and proportionately for differences in diameter; the whole filament thus becomes homogeneous and uniform in resistance throughout, no section tending to heat more than another.

As the carbon is deposited the resistance decreases and the current increases. The pointer of the ammeter moves along the scale to an indication where the desired resistance, and consequently current, has been reached; at this point the pointer closes a circuit which automatically shunts in a current from another circuit and which in turn throws out the switch clutch; the switch springs open and cuts off the current from the filament, stopping any farther deposition of carbon.

It is optional whether the filament be suspended in the vapor above the liquid in the bottle or be submerged; results of test show that filaments flashed in the vapor are less likely to cause blackening of the bulb than when treated by submerging. The latter process is sometimes used because it is the cheaper and is also the safer from explosions occasioned by access of air.

In making the filament the length and cross-sectional area are the considerations sought in homogeneous material in determining the resistance for a required candle-power at the voltage at which the lamp is to be burned.

Filaments of the 150 c. p. diving lamp are made either of tamadine or carbonized split bamboo, but neither style of filament have as yet proved successful in this type of lamp.

Tamadine filaments are usually known to the trade as "squirted" filaments.

Figs. 3 and 4 show the different types of filaments of naval incandescent lamps. The spiral type (*C*, Fig. 3) was used in 80-volt lamps of 16 and 32 c. p., having the old cruiser type of

bulb, now obsolete. The oval type (*E*, Fig. 4) is used in those having the present parachute standard bulb for the 16 and 32 c. p., and in the 10-candle-power telephotos lamp. The practical difference between the oval and spiral filaments is that the oval is anchored while the spiral is not.

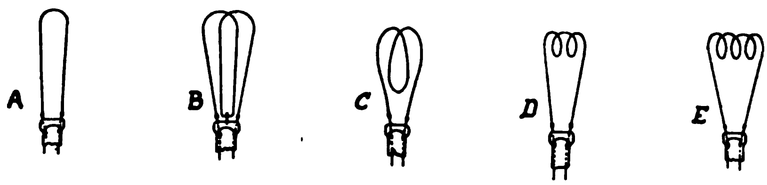

FIG. 3.—Types of filaments.

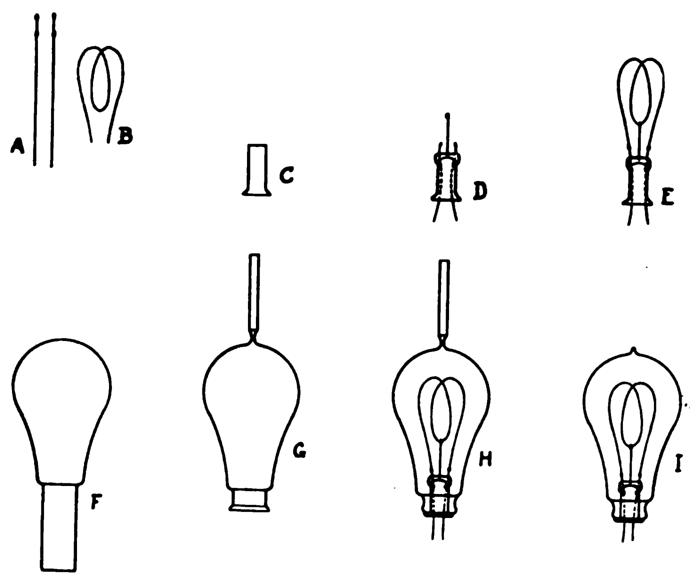

FIG. 4.—Stages of lamp assembly.

The filament of the 150 c. p. diving lamp is made in a two-coil spiral (*D*, Fig. 3) for the 80-volt type; that for the 123- and 110-volt types is a double loop, or double "horse shoe" (*B*, Fig. 3), the loops being set at right angles and in series with each other.

The filament of the 5 c. p. is a two-coil spiral (*D*, Fig. 3). That of the 2 c. p. is a double loop for the 80-volt type and a three-coil spiral (*E*, Fig. 3) for the 123-and 110-volt types.

The filament of the 1 c. p. lamp is a single loop (*A*, Fig. 3),

as is also that of the 6 c. p. torpedo lamp; the long filament of the 6 c. p. is ordinarily anchored to the tip of the bulb instead of to the flyer to obtain better centering and steadiness.

The Flyer.—Two 3-inch copper leading wires are first attached to two platinum wires, each about ½ inch in length (*A*, Fig. 4); the copper wire is heated in a blow lamp and the platinum wire forced into the fused end of the copper, making a secure joint. Notwithstanding the comparatively great expense entailed by the use of platinum for these lamp ends (which are to be fused into the glass of the flyer) no other metal so well serves the purpose: first, because platinum will not oxidize at the high temperature necessary for fusing the glass, hence the joint will be tight and not cause a leakage of air into the vacuous space; second, as the coefficients of expansion of glass and platinum are practically the same, the expansion of the metal is not likely to crack the glass of the flyer and admit air.

The combination of the copper and platinum leading wire is next assembled in a glass tube having a bell-shaped mouth (*C*, Fig. 4), the platinum wire being fused in the glass. The finished flyer is shown at *D*. The wire shown in the center of the flyer is of metal, usually copper, and is called an anchor; its office is to secure the bottom of the filament spiral, thus centering the filament, steadying it against vibration, and preventing it from swinging against the glass of the bulb; it requires but a light touch of the incandescent filament to fuse the glass, collapse the bulb at the point of fusing, admit air, and destroy the filament.

The filament ends (*B*, Fig. 4) are next attached to the platinum wires of the flyer, and the spiral to the anchor, by a non-fusible cement, or carbon paste, called a "*clamp*"; the date of manufacture is written in ink on the surface of the glass of the flyer, and the combination of this stage (*E*, Fig. 4) is ready for inserting in the bulb.

The length of the flyer for the 80-volt, 110-volt, and 123-volt types is not the same, due to the difference in length of the filament.

The Bulb.—The construction of the bulb is purely a glass manipulation. *F*, Fig. 4, shows the bulb as received from the glass factory; *G*, at the stage at which the flyer is fused in.

The assembly of the bulb and flyer consists in carefully inserting the combination shown at *E*, Fig. 4, into the bulb, *G*, and

fusing the edges of the bell mouth of the flyer to the edge of the bulb; the finished product is shown at *H*, in which stage the lamp is ready for exhausting.

Commercially standard bulbs are generally denoted by a number which represents their diameter in eighths of an inch; thus a 2⅝-inch bulb is designated as No. 21.

Forming of the Vacuum.—Upon the best performance of this office depends that vital consideration, the life of the filament, and consequently the life of the lamp; the *rationale* of the method is the elimination of oxygen.

The narrow tube which is shown attached to the top of the bulb, *H*, Fig. 4, is coated internally with a red chemical compound, a trade secret, but containing red phosphorous which takes up the residual oxygen in the bulb when heated forming a transparent phosphoric acid gas. The end of the narrow tube is next inserted in the air-tight rubber bushing of a tube connected with a mechanical, Sprengel, or Weston, type of air pump and exhausted until the attached column of mercury shows about 30 inches. The copper leading wires of the lamp are now attached to clips on two wires which are fed at the potential at which the lamp is to be run and the current is turned on. The color of the bulb will now be a *pale blue*.

A blow-pipe flame is applied gently to the narrow tube until the red chemical volatilizes and disappears and the lamp shows a *clear or bright yellow;* the narrow tube is then gently seared over (" sealed ") next the bulb and twisted off, leaving the little nipple generally seen on incandescent lamps. *I*, Fig. 4, shows the lamp at this stage.

The bulbs are now tested for vacuum by brushing the leading wires against a plate attached to one electrode of a Ruhmkorff coil, the lamp being held in the hand. The sufficiency of the vacuum is judged by the color and the appearance of the light inside. The bulb is then ready for the base.

Attaching the Base.—The Edison base consists of a threaded spun brass open-ended cylinder, perforated with one hole near the middle of its length, and a brass disc perforated through its center. The method of attaching the base, using plaster of paris only, is as follows:

The combination (*I*, Fig. 4) is put in a frame moving perpendicularly, the cylinder is centered under the frame and the disc

is entered at the bottom of the cylinder. The copper leading wires are threaded, one through the perforation of the cylinder, the other through the center of the disc, and the cylinder is filled with plaster of paris.

The frame is now pushed down and the wires drawn through. As soon as the plaster hardens the overflow is trimmed off, the leading wires are cut close to the cylinder and disc and soldered. The bottom of the base is then coated with shellac and the lamp is finished. This method, though common, has the serious objection that, notwithstanding the protection afforded, the shellac proves unequal to keeping out moisture when the lamps are stored in such moist locations as ship store-rooms; the plaster of paris being hygroscopic, sufficient moisture is taken up to cause a short circuit between the copper leading in wires in the lamp base which cannot be readily removed by drying.

A second method considerably in vogue is to crimp the bottom of the cylinder and cement in a treated porcelain plug or button in which the brass disc is imbedded; the bulb is secured to the cylinder by a moisture proof cement. The porcelain plug has channels for the leading wires to the disc, and to the side of the cylinder, or to a bottom edge if so connected. It is important that the porcelain insulate between the leading wires. The channels should be carefully filled with some water repellent substance. The method has the same objections cited for plaster of paris, but in a lesser degree.

The latest method, in which a glass plug is used instead of porcelain, is an improvement on the last. The plug is made by forming melted glass in the crimp of the base, the contact piece being secured by rivet attachment. In this method but one channel is necessary, the other leading in wire being soldered at the top of base.

The bases of the 150, 32, 16, and 10 c. p. lamps are required to be of standard form of Edison base. The base of the 5 c. p. is of the candelabra form of Edison base. The bases of the 2 c. p. and 1 c. p. are of the minature form of Edison base.

Test of Voltage.—The lamps are next "run through" a photometer to measure the voltage at which the rated candle-power is maintained, the screen being moved along a scale marked in volts, the lamp rotating at 180 revolutions per minute. All that is sought in the commercial test is to ascertain what voltage the

particular lamp requires for the rated candle-power; this complying with specifications, the watts per candle-power and actual candle-power are taken as correct. Lamps have heretofore been marked for the rated candle-power and rated (not actual) voltage; a mark showing the actual voltage to the nearest volt is now shown on the label.

Life Test.—A number are selected and started on a life test (useful life being tested) for loss of candle-power in the interval.

Frosting.—The bulbs of those lamps which are to be frosted are, after being tested for voltage, submerged in a solution of hydrofluoric acid and ammonium chloride; the operation requires but a fraction of a minute.

Inspection and Test of Incandescent Lamps.[*]

In order that there may be no misunderstanding as to what will be expected of a delivery of incandescent electric lamps the inspection and tests which the lamps will be subjected to are prescribed in the specifications substantially as follows:

All lamps are to conform in their general shape and form to the official drawing, from which Fig. 1 is taken.

The overall dimensions of the standard 32, 16, and 5 c. p. lamps must not exceed the dimensions in inches in the following table, in order that they may fit in the standard types of fixtures:

TABLE I.

	32 c. p.	16 c. p.	5 c. p.
Length overall	$4\frac{7}{8}$	$4\frac{7}{8}$	$2\frac{7}{8}$
Length of bulb without tip	$3\frac{11}{16}$	$3\frac{11}{16}$	2
Maximum diameter of bulb	$2\frac{5}{8}$	$2\frac{1}{2}$	$1\frac{3}{8}$

The overall dimensions of the 150 c. p. (diving), 10 c. p. (telephotos), and 2 c. p. and 1 c. p. (instrument), and 6 c. p.

[*] All inspections and tests herein explained are those in current practice in the Equipment Department of the New York Navy Yard.

For the sake of brevity, it may be here stated that in addition to items of specification (which are alone taken up in the descriptions following), the blank forms used by that department, largely inaugurated in the department itself, are made complete as to details and features of the article under inspection, the marks of manufacturers, workmanship, accessories, dimensions—in short, any detail for recognition, future requisition, or incidental and necessary to repair. A photograph of a new article is always taken in three views, and often the whole is disassembled and all parts photographed.

(torpedo) lamps must conform to the dimensions shown in the official drawing.

The lamps must be made of the very best materials, and must be of the best quality and finish and uniform in size.

The filaments must be centered in the bulb and, in the case of the 32 c. p. and 16 c. p. lamps, must be anchored. They must not droop appreciably during the life of the lamp when the lamp is run in a horizontal position.

Each lamp must have its rated candle-power and the voltage (to the nearest volt) necessary to give this candle-power, and the name or trade-mark of the maker shown on a printed label or otherwise clearly or indelibly marked on the bulb.

The lamps must be so designed that when burned at the rated mean horizontal candle-power the volts and total watts will not fall outside of the limits prescribed by the table on opposite page.

Measurements for mean horizontal candle-power are to be made by revolving the lamps at about, and not less than, 180 r. p. m. with the axis of the lamp vertical. When making this determination the lamps shall be so placed in the photometer that the horizontal line through the center of the screen will cut the lamp at its maximum diameter.

From each barrel or lot of 200 lamps there will be selected at random 10 lamps for the purpose of determining the initial voltage, and the total watts at the rated candle-power, and the physical characteristics of the lamps. These lamps will be known as test lamps. If the voltage or total watts of any two of the test lamps from any barrel or lot of 200 lamps is found to fall beyond the limits allowed in Table 2, above, 10 more lamps will be selected at random from the same barrel or lot, and if any one of these additional lamps is found to fall beyond the allowed limits of voltage and total watts, the entire barrel or lot will be rejected without further test. If the voltage or total watts of more than two of any lot of 10 test lamps falls beyond the allowed limits, the barrel or lot from which these lamps were selected will be rejected without further test. If any one of the 10 test lamps selected from any barrel or lot of 200 lamps shows a poor vacuum, a loose base, a spotted or discolored filament, or any other physical defect incompatible with good workmanship, good service, or with any clause of these specifications, 50 lamps will be selected from this barrel or lot, and should 10 per cent of these 50 lamps

TABLE NO. 2.

1	2	3	4	5	6	7	8	9
Class.	Rated candlepower.	Standard total watts.	Type of filament.	Individual voltage limits.	Individual total watt limits.	Candle hour area at rated efficiency.	Candle hour area at 3.1 W. P. C.	Test candlepower to give 3.1 W. P. C.
SPECIAL LAMPS.								
Instrument.								
1 candlepower 10 volts, clear....	1	4.9	Loop........	9.25–10.75	4.5– 5.3	552	68	2.02
2 candlepower, 80 volts, clear....	2	11	Double loop..	78– 84	10.1–11.9	1,288	92	4.79
2 candlepower, 110 volts, clear...	2	13	3-coil spiral..	106–116	12–14	1,472	55	6.1
2 candlepower, 123 volts, clear...	2	13	....do......	119–129	12–14	1,472	55	6.1
Torpedo.								
6 candlepower, 80 volts, clear....	6	30	Loop........	77– 85	27–33	138	15.4	12.5
6 candlepower, 110 volts, clear...	6	30	....do	106–116	27–33	138	15.4	12.5
6 candlepower, 123 volts, clear...	6	30	....do......	119–129	27–33	138	15.4	12.5
Telephotos.								
10 candlepower, 80 volts, clear....	10	36	Oval........	73– 83	34–38	3,680	1,840	12.5
10 candlepower, 110 volts, clear...	10	36	....do......	104–112	34–38	3,680	1,840	12.5
10 candlepower, 123 volts, clear...	10	36	....do......	119–127	34–38	3,680	1,840	12.5
REGULAR LAMPS.								
Regular.								
5 candlepower, 80 volts, clear....	5	19.5	2-coil spiral..	80– 86	18–21	2,760	1,200	7.14
5 candlepower 110 volts, clear...	5	19.5	....do......	110–117	18–21	1,150	800	7.14
5 candlepower, 123 volts, clear...	5	19.5	....do......	123–131	18–21	1,150	500	7.14
16 candlepower, 80 volts, clear....	16	56	Oval........	77– 82	53.2–58.8	12,000	8,000	19
16 candlepower 80 volts, frosted .	16	56	....do......	78– 83	53.2–59.8	12,000	....	19
16 candlepower 110 volts, clear...	16	56	....do.....	107–112	53.2–58.8	12,000	8,000	19
16 candlepower 110 volts, frosted.	16	56	....do......	108–113	53.2–59.8	12,000	....	19
16 candlepower, 123 volts, clear...	16	56	....do......	121–125	53.2–58.8	12,000	7,000	19
16 candlepower, 123 volts, frosted.	16	56	....do......	122–126	53.2–59.8	12,000	....	19
32 candlepower, 80 volts, clear....	32	115	....do......	76– 82	109–121	20,000	11,000	40
32 candlepower, 110 volts, clear...	32	115	....do......	106–112	109–121	20,000	11,000	40
32 candlepower, 123 volts, clear...	32	115	....do.	120–126	109–121	20,000	11,000	40
Diving.								
150 candlepower, 80 volts, clear ...	150	465	2-coil spiral.	76– 82	442–488	13,800	13,800	150
150 candlepower, 110 volts, clear...	150	465	2 loop.......	106–112	442–488	20,700	20,700	150
150 candlepower, 123 volts, clear...	150	465	....do......	120–126	442–488	20,700	20,700	150

[NOTE 2.—Frosted lamps are not tested at 3.1 w. p. c.]

be found to have any of the physical defects above mentioned, the entire lot from which these lamps were selected will be rejected without further test.

From the 10 test lamps selected from each barrel or lot of 200 lamps passing the above tests for voltage, total watts, and physical characteristics, one lamp shall be selected and shall be known as a life lamp. This lamp shall be the one from each lot of 10 test lamps which measures closest to the mean of the limits for volts and total watts as given in columns 5 and 6 of Table 2, above. From the life lamps so selected a given number will be tested for candle-hour performance, and this test will be known as the life test. The number of lamps that will be put on life test will depend upon the number of lamps delivered.

When lamps are purchased in lots of 2000 or less, 10 lamps will be selected for life test; in lots of from 2000 to 5000, 20 lamps will be selected; in lots of from 5000 to 10,000, 30 lamps will be selected; in lots of from 10,000 to 30,000, 50 lamps will be selected for life test. The lamps selected for life test will be brought to that value at which the lamp burns at 3.1 watts per mean horizontal candle-power. Throughout the life test each lamp will be burned at the particular voltage which was required to give 3.1 w. p. c. initially. The average value of the candle-hour performance of the lamps subjected to life test shall not be less than the amount in column 8, Table 2, above.

The candle-hour performance of a lamp will be calculated, as described below, from the observed values of the mean horizontal candle-power measured at the beginning of the life test, and at intervals thereafter of 25 hours during the first 100 hours, and thereafter at intervals of not more than 100 hours until the lamps shall have burned out, or fallen to 80 per cent of its test candle-power. In case a lamp burns out, its candle-power at the time of the burn-out will be assumed equal to the last observed candle-power. The candle hours given by a lamp during any one of the intervals of 100 hours or less, as above, will be considered to be the product of the hours denoting the duration of that interval, and the arithmetical mean of the observed values of the mean horizontal candle-power measured at the beginning and at the end of such interval; provided, that if any observed value of the mean horizontal candle-power exceeds the test candle-power by more than 3 per cent, such candle-power shall, in computing the

candle hours, be given a value of 3 per cent greater than the test candle-power. The candle-hour performance of the lamps will be considered as the sum of the candle hours given during each of the observed intervals, and up to that time when the lamp shall have burned out or shall have fallen to 80 per cent of its test candle-power.

Test for vacuum will be made with an induction coil previously set for a ⅜-inch spark for regular lamps, and suitably reduced for small lamps having delicate filaments.

The standards of candle-power which will be used in making the above-described tests will be those held in the Equipment Department at the Navy Yard, New York. Any person having a contract for lamps may send to the Equipment Department, Navy Yard, New York, a set of 10 seasoned lamps to be standardized, one-half of which will be returned, and the other half retained for future reference.

All lamps whose bulbs shall burst, or whose filaments shall break under test or in transit will be rejected from the delivery, and must be replaced at the expense of the contractor. In order to avoid duplication of the life test, no test will be made on any class of lamps until the entire number of such lamps on any contract is delivered, unless it is specified in the contract that partial deliveries are to be made at stated times. In case partial deliveries are required, the entire quantity of each class of lamp constituting the partial delivery must be received before any tests will be undertaken.

Mechanical Construction.—The maximum diameter of the bulb is tested by means of a gauge ring which has an inside diameter equal to the greatest allowed diameter of the lamp, as per table; the lamp must pass through this ring without effort. Two or three other diameters of the bulb and the diameter of the base are calipered. Lengths are measured for correspondence with the prescriptions of the standard drawing. These dimensions are important, to insure fit in standard fixtures.

Examination is made of the following:

That the threads of the base are of the prescribed number and pitch, in order to insure a fit in the standard socket.

That the bulb is securely cemented to the base, and that the cement is moisture proof; tested by placing the lamp under water for an hour or two and wrenching the base.

be found to have any of the physical defects above mentioned, the entire lot from which these lamps were selected will be rejected without further test.

From the 10 test lamps selected from each barrel or lot of 200 lamps passing the above tests for voltage, total watts, and physical characteristics, one lamp shall be selected and shall be known as a life lamp. This lamp shall be the one from each lot of 10 test lamps which measures closest to the mean of the limits for volts and total watts as given in columns 5 and 6 of Table 2, above. From the life lamps so selected a given number will be tested fo candle-hour performance, and this test will be known as the li test. The number of lamps that will be put on life test w depend upon the number of lamps delivered.

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That the button is so placed that it will insure insulation between the contacts and that the channels are fitted with a water-repellent substance. After the soaking test the lamp is placed in a socket; if short-circuited it will not burn or will burn faintly.

That the leading-in wires are securely soldered to the bottom contact and to the side cylinder; and that they are of copper and have platinum ends in the fused part of the flyer.

That the filament is centered in the bulb and, if anchored, that the anchor is of metal and is securely fused into the flyer.

That the quality and finish is of the best, judgment being rendered by comparison with a standard sample.

That the lamp is properly labeled for its rated candle-power and the actual voltage, to the nearest volt, which is required to give that candle-power.

That the filament is securely fastened to the leading-in wires and to the anchor. Usually this determination is not definitely demonstrated by examination; as a rule the performance of the lamp on life test will show it, as the filament is likely to separate from the platinum wire if the clamp is poor.

The date of manufacture must be noted, and if not within three months of the date of delivery examination of records is made to insure that the lamp is not of a lot that has been previously tested and rejected.

Photometer Test.—In ordinary photometer tests the problem is to ascertain the unknown candle-power of a source of light by comparison with a standard flame or candle, and, incidentally, the rate of consumption of the material which maintains the source. In photometric measurements of incandescent lamps the problem is to ascertain the consumption of electric energy in a lamp of designed, or *rated,* candle-power by measuring its voltage and current when burning at that candle-power; the product of these two measurements gives the total watts consumed, from which the efficiency can be calculated by dividing by the candle-power.

The photometer used is shown in Fig. 5; it was constructed at the navy yard.

The bed of the photometer, *A,* is a steel I-beam mounted on heavy cast-iron standards. It carries a steel scale, divided, first, to read directly in candle-power; second, in tenths of an inch

over a length of 60 inches, the total distance between sockets for the standard lamp and the lamp under test.

The photometer carriage, *B*, runs on ways provided on the upper side of the photometer bed, and carries the photometer screen, *C* (the Lumner-Brodhun is shown, the ordinary Bunsen screen is shown detached at *D*). The screen has an index line

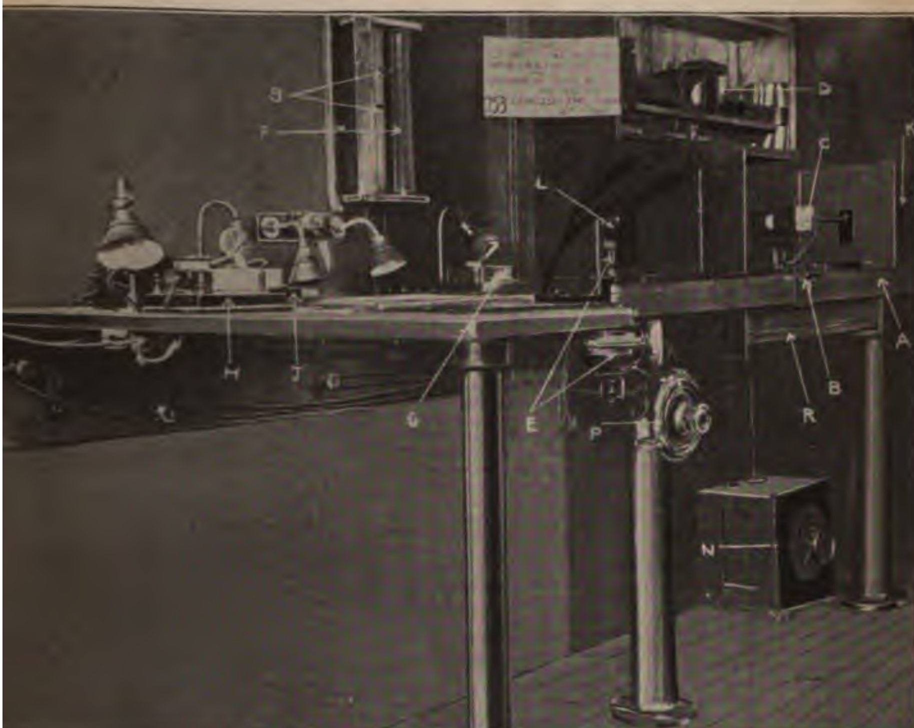


Fig. 5.—Photometer, New York Navy Yard.

giving its exact center with reference to the photometer scale; a pin fixes the screen at the 16 c. p. and 32 c. p. divisions, on its rear side is a clamp for holding at any position. For taking readings on lamps of unknown candle-power (when the carriage is to be varied in position) an instrument lamp is provided which illuminates the photometer scale at the index line; this is lighted by pressing a button, also on the carriage.

At the right-hand end of the photometer is the socket, *K*, for

the standard lamp, which can be turned about its vertical axis to any angle, as indicated by a graduated circle, and clamped fast in the position by a set screw. An adjustment for height (by collar and set screw) are also provided; when correctly set, the center of the loop in the lamp filament will correspond with the center of the photometer screen.

The rotator, *E*, for the lamp under test, *L*, is at the left-hand end of the bed. This consists of a socket rotated at a constant speed of 180 r. p. m. by a direct-connected, 1/6 h. p., motor; electrical connection is made to the lamp by means of two mercury cups. The speed of the motor is regulated by a rheostat of the Carpenter type, *P*. The motor is stopped and started while the lamp is being replaced by a switch operated by the laboratorian's foot. A snap switch is provided in the rotator circuit.

The rheostat, *F*, regulates the voltage of the standard lamp; it is wound with No. 22 German silver wire, total resistance 69.5 ohms. The insulated resistance wire is spooled over a brass tube and a section of the surface is bared for contact with sliders, *S*, in series with the rheostat and the standard lamp. When the sliders have been advanced to the "all-out" positions on the rheostat resistance, there will still be a resistance of 1.5 ohms in circuit due to the rheostat.

The rheostat is so located as to be conveniently in reach of that observer who is reading the voltmeter, *G*, which is connected across the standard lamp, and the voltmeter, *H*, and ammeter, *J*, connected for reading the voltage and current of the test lamp.

The rheostat, *R*, similar in construction to *F*, is in the circuit of the lamp under test, and is placed on the photometer bed so that the observer at the screen can adjust the voltage of the test lamp to that necessary for obtaining the proper intensity of light on the test lamp side of the screen. Three coils are shown in the rheostat, of which the smaller is for fine adjustment of the voltage.

When the intensity of the light on both sides of the screen is equal (or "balance" has been obtained) the voltmeter, *H*, will indicate the voltage of the test lamp for balance. The rheostat, *N*, is used as a shunt for tests of the 150 c. p. lamp, whose current, 6.25 amperes, would be likely to burn out the rheostat, *R*, if *N* were not paralleled across the circuit.

The voltage of the standard lamps varies from 48 to 50 volts, but the rheostat, *F*, contains enough resistance to cut down the line voltage to the proper value for these lamps when 125-volt lamps are under test.

The rheostat, *R*, controlling the lamp under test is wound with No. 18 German silver wire; total resistance, 54.7 ohms.

Resistance of top coil.................24.7 ohms.
Resistance of 2d coil................. 7. ohms.
Resistance of bottom coil.............23. ohms.

Reading lamps are placed over the instruments and are so shaded that light is thrown on the instrument scales only. These are instrument lamps of 2 c. p. at 80 volts, a 32 c. p. lamp being placed in series to cut down the voltage from the 110 volts necessary for the motor.

The Bunsen Screen.—A spot of grease on a sheet of white paper is placed normal to the optical axis of the photometer; the spot disappears when the paper is equally illuminated on both sides. The spot is central and the field is viewed by 45-degree mirrors set on each side of the screen.

The paper used is Whatman's I A H double elephant; the grease spots are prepared by dipping a warmed disc of brass, about 5/8-inch diameter, into a paraffin bath; this, after dripping a little, is pressed on a large sheet of paper in a number of places and the excess paraffin removed from the spots by the aid of a sheet of blotting paper pressed by a moderately hot flat-iron. The best spot is then chosen.

The photometer should readily show a difference of 2/10 volt in a 3.6-watt, 80-volt, 16 c. p. lamp with the Bunsen screen, one lamp revolving. With the Lumner-Brodhun screen and stationary lamps, as in checking standards, observations by two persons should check within 1/10 volt.

The Lumner-Brodhun Screen is shown in diagram in Fig. 6 It consists of a gypsum, or MgO screen, held normal to the optical axis, each face of which is illuminated by one of the lamps under comparison. Two prisms are provided, one of the hypothenusal sides being so recessed and held as to be in contact only at a portion of the length, as shown. The eye at the reading telescope sees a uniformly illuminated field when the faces of the screen are equally illuminated. One face of the screen is seen by

reflected light, the other by the light transmitted through the prisms; this is reversed by turning the box through 180 degrees, the surface seen in the first position by reflection being seen by transmitted light in the second.

The trapezoidal-shaped figures of the sight field are illuminated by light from the regions marked 4 and 5 only; the light of the regions 2 and 7 does not pass to the eye piece at all and the *field,* as distinct from the trapezoidal *figure,* is illuminated from the test lamp source by the rays 6 and 8 and from the standard lamp by the rays 1 and 3. Hence, there will be contrast between the figure illuminated by 4 and the field illuminated by 1 and 3 on each side of it, and similarly there will be contrast between the figure illuminated by 5 and the adjacent field illuminated by 6 and 8 but in the opposite sense to the contrast for the figure illuminated by 4. There will also be a contrast at the medial line of the sight field between the spaces illuminated by 3 and 6. These three contrasts in different positions enable the operator to check his balance quite accurately, and more so than is practicable with the Bunsen screen.

The Lumner-Brodhun screen can also be fitted with absorption strips (as shown in the path of the rays 1, 3, 6, and 8), interposed in the path of the light from both of the sources; their use is unnecessary when the lights from the two sources are of the same color, and are used only when the lights from the two sources are of different colors.

The rays 1 and 3 from the standard source, and 6 and 8 from the test source, pass through the absorption strips to illuminate the fields but do not illuminate the trapezoidal figures, the figures being illuminated by the active light from each source. There are, therefore, two methods of comparison; by contrast of the active lights from the sources, and by contrast of those active lights as affected by absorption, the comparison being made by contrasting the illumination of the trapezoidal figure with the field immediately adjacent to it. There is also the difference in illumination across the medial line of the sight field, or three ways can be utilized as before but, due to the absorption strips, the contrast between the trapezoidal figures and the adjacent fields will be intensified.

In testing, a Tertiary standard lamp is placed in the socket at *K* (Fig. 5), and used as a standard for the lamps to be tested; it

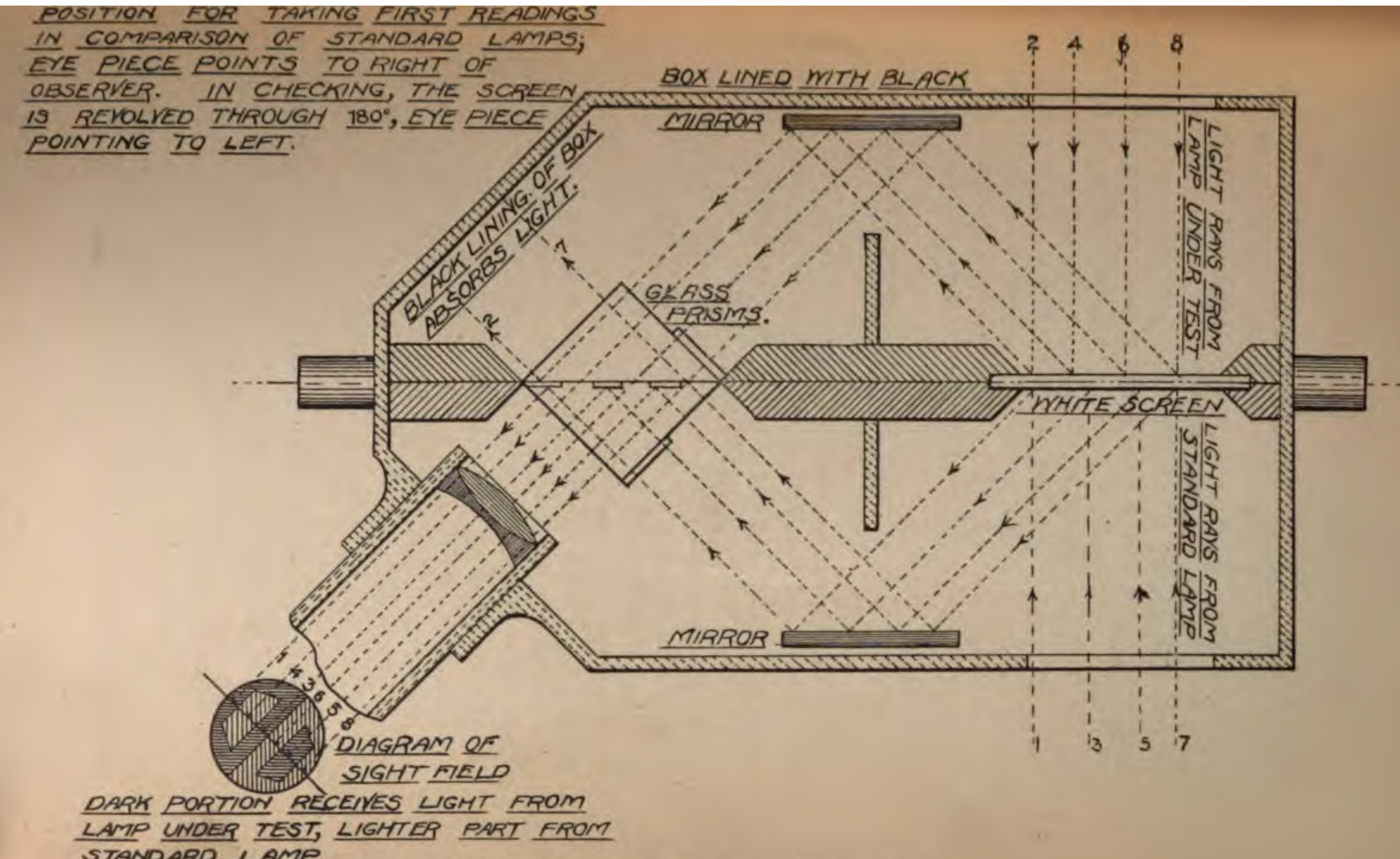


Fig. 6.—Diagram of the Lumner-Brodhun screen.

is fixed by the circular scale so that the plane through its filament will be 60 degrees from that of the optical axis of the photometer. Its voltage, as determined in standardization and as recorded by the voltmeter, *G*, is kept constant for any fluctuation of the line voltage by the rheostat, *F*. The lamps under test are mounted consecutively in the socket, *L*, which is kept revolving at 180 r. p. m. by the motor, *E*, and the voltage of the test lamp is varied by the rheostat, *R*, until equal balance is shown on the screen, when the voltage as indicated by the voltmeter, *H*, and the current, as indicated by the ammeter, *J*, are read. To avoid cracking or scratching the bulbs by contact, which weakens the vacuum, all lamps are handled in the racks only after unpacking.

The number of lamps tested is governed by the specifications above cited.

In order that a representative lot of lamps be tested, the lamps tested are selected equally from all the barrels or packages in the shipment, except in case one or more barrels or packages contain lamps of mixed voltages; in that case the test lamps are so selected that the percentage of each voltage is the same percentage as the number tested is of the number represented by the test, care being taken that some lamps are selected from each barrel or package.

Each lamp is marked in ink on its label with a serial number. This identifies the lamp during the test and upon the records. Failures are recorded by a check mark in the proper column of the test record form opposite the test number of the lamp failing.

The mercury contacts on the rotating socket should be clean, well amalgamated, and have sufficient mercury in the cups to insure good contact. The rotating socket should be tried to see that it can be driven at 180 r. p. m. and that it will maintain that speed.

Care should be taken that all working parts of the Bunsen screen are clean and that the two sides are in exactly the same condition. Only a soft chamois cloth is used for cleaning the working parts and a soft camel's hair brush for dusting the screen. These directions apply to the care of the Lumner-Brodhun screen also. When either screen is perfectly clean the direct and reversed readings will be exactly the same. Great care must

be exercised in cleaning the Lumner-Brodhun screen to avoid injury to any of the delicate parts.

Before starting to test a voltmeter is checked daily with the laboratory standard voltmeter at the voltages at which it is to be used, and the photometer voltmeters calibrated to conform to it. These photometer voltmeters must be adjusted every time a voltage differing a few volts from that last used is to be read on them. Adjusting by means of a magnetic shunt obviates the necessity of correcting each reading as it is taken.

The ammeter which is to be used is calibrated daily by checking it with the laboratory standard ammeter.

Care should always be taken that no lamp is subjected to a voltage higher than its rated voltage. To accomplish this always have both photometer rheostats "all in" before starting a test.

In standardizing, since the laboratory tertiary standards are 16 c. p., for a lamp of any other candle-power the screen would be placed at that distance on the bar scale from the standard lamp which would accord with the law that the intensity of light varies inversely as the square of the distance; in standardizing a 5 c. p. lamp the screen would, therefore, be set at 6.4 inches on the scale bar from the lesser candle-power, or 53.6 inches from the standard 16 candle-power. The positions for the different types of lamps are, however, marked on the photometer bed, *A*.

There are two considerations of the foregoing test which deserve some passing explanation; they are the *mean horizontal candle-power* and the *standardization*. The first question is what is to be the relation of the filament of the test lamp to the optical axis of the photometer when the lamp is emitting its mean available candle-power. It is not a question as to the standard lamp because that lamp is standardized for the fixed 60-degree position and should obviously be so set.

Two candle-powers are recognized in lamp tests, one given out at the end of the filament, or end candle-power, the other given out at the side of the length of the filament, or horizontal candle-power. A lamp constructed with a filament running straight through would evidently have no end candle-power at all, and, in general, the end candle-power will be less than the horizontal for any type of filament. This suggests that a lamp be so installed in the ship as to emit its light at the side rather than at the

end and that, for overhead lighting, the lamp should be laid flat if the side illumination is to be lost in the particular location.

Whether the test lamp shall be set with its axis in continuation of the optical axis of the photometer, end on, or with its axis in, but perpendicular to, that optical axis, has been a mooted point; it is now the recognized practice to adopt the latter method as a better comparison with the usual and necessary practice as to gas flames, etc., and the horizontal candle-power method is very generally accepted.

The method of test of candle-power by fixing the plane of the filament at the best angle for the determination of a good mean is found not to be as fair to the lamp as the determination by rotating at a necessary speed, as the mean horizontal candle-power determined by the latter method is in excess of that for which a comparable mean could be measured for the same lamp when in the fixed position.

Another method of testing, by mean spherical candle-power, deserves no particular mention as it is practically the same in result as the mean horizontal.

The second question, standardization, is dependent upon the reliability of the official reference standards. The Equipment Department of the Navy Yard, New York, is in possession of 18 of the very best standard 16 c. p. lamps extant. These lamps were carefully constructed by the General Electric Company for the especial purpose and were selected as the best of the number of well-seasoned lamps so constructed. They have a loop (horseshoe) filament and operate at between 48 and 50 volts, taking from 1.18 to 1.2 amperes to produce 16 c. p. when at the 60-degree angle. The lamps were standardized by the Physikalish Technische Reichsanstalt, of Charlottenburg, Germany, in comparison with the Hefner Alteneck Amyl-acetate lamp. In determining the candle-power the ratio of the English Parliamentary Standard Candle of 46 millimeters (1.773 inches) flame height to the Hefner lamp is taken as 1.14 to 1.0.

The comparison was made both when revolving at 180 r. p. m. and when the plane of the filament was 60 degrees from that of the center line of the photometer, on the line marking the 60-degree position toward the disc.

The best nine lamps are used as primary standards and are marked P-1, P-2, etc. The remaining nine are the secondary

standards and are marked S-1, S-2, etc. From these standards 20 other lamps were standardized; they are known as the tertiary standards (marked T-1, T-2, etc.), and were made and selected for the purpose at the same time as, and are exactly like, the primary and secondary standards.

The standard lamps are handled by laboratorians only. Four primary, four secondary, and five tertiary standards are buried

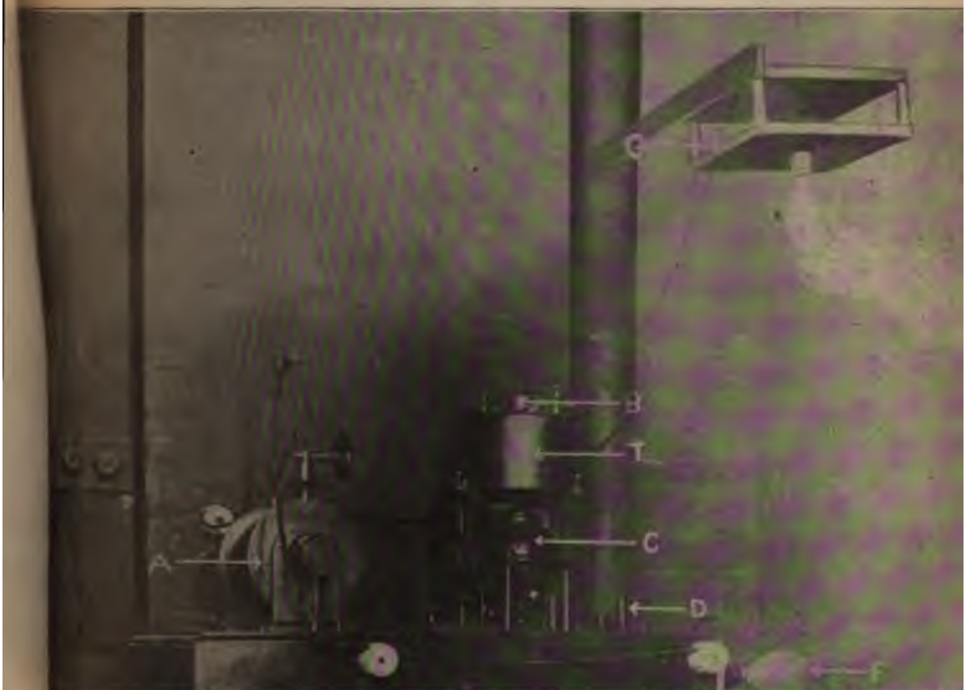


FIG. 7.—Apparatus for vacuum test.

in an air-tight box to avoid loss of reference standards in case of fire. The secondary standards are checked with the primary standards every six (6) months, January and July, and the tertiary with the secondary every month except when no lamps have been under test during that month. The Lumner-Brodhun screen is always used for these tests.

Whenever a lot of new lamps are to be tested one of the tertiary standard lamps is used as the working standard; a lamp taken

from the lot will not suffice as, not being properly seasoned, its candle-power will not remain constant. In order to give the same amount of use to each of the tertiary standards they are used in rotation.

The Vacuum Test.—The vacuum test is made after the photometer test. The vacuum tester is shown in Fig. 7, and the manner in which a lamp is held while testing.

The tester is a Will-young X-ray apparatus. The induction coil, *A*, has its primary connected to an interrupter which differs from the ordinary type in being rotary instead of vibratory. The interrupter, *B*, is attached to the shaft of a Lundell 1/12 h. p. motor, *C*, by which it is driven at a speed of 1500 r. p. m., making 75 breaks a second, or three per revolution; the breaks are made under water, the interrupter being enclosed by a copper tank, *T*, for the purpose. The reversing switch, *D*, is connected to the primary circuit; it changes the direction of the current in the primary coil and interlocks with the motor switch so that the latter cannot be turned off with the reversing switch left at *on* point.

The condenser is of the ordinary type and made up of tin foil and paraffined paper. One electrode of the secondary of the coil is connected to an insulated metal plate, *G*, and the other to both terminals of the lamp, *F*.

The X-ray machine is regulated to give a spark of about three-eighths of an inch in length for regular lamps; for lamps of 5 c. p. and below a ¼-inch spark is used. The spark gap should be rather less than more than this. The terminals are, after the machine is regulated, set at a greater distance apart so that no spark passes between them.

The lamp to be tested is then held in the hand, grasping it by the bulb, and its base brought into contact with the metal plate, *G*.

If the vacuum is very poor the lamp will glow all through *even before it touches the plate.* If it is better than this, but still not good, there will be a glow all through the lamp when its termals touch the plate.

If the vacuum is good enough there may still be a considerable amount of glow, but it will all appear on the *inside surface of the glass,* and not at all in the interior of the lamp.

The glow in the interior of the lamp in the case of a bad vacuum will be of a blue color, or, if the vacuum is very bad, of a

purple color. In the case of a good vacuum, when there is a glow upon the glass only, it will be blue if the bulb is made of lead glass, but of a green color if German glass is used. In the case of a good vacuum the glow on the glass is intermittent and only appears in patches or there may be no glow at all.

With a good vacuum while one hand holds the lamp to the plate the other hand may grasp the lamp, F, connected to the other terminal of the X-ray machine with impunity; while, if the vacuum is bad, a shock will be felt. The experiment is dangerous if the frequency is low.

The coil or inductorium test, while good, is not infallible. A lamp which shows a poor vacuum may, by being run very bright on the photometer for a minute or two, be made to show a good vacuum on the coil, no trace of any glow being perceptible. A clouded appearance of the glow, as if the interior were filled with steam, is a sure indication of a bad lamp whatever the color.

A lamp which, when run at rated voltage, shows blue is a bad lamp and requires no farther vacuum test.

The Life Test.—The life test is practically crucial as to filaments demonstrating the sufficiency of the construction by the test of endurance, the quality of the treating (flashing) by the amount of deposit on the interior surface of the bulb, and the integrity of the clamp under protracted heated conditions. The test also determines in a way the sufficiency of the vacuum, as with a poor vacuum the filament will soon burn out; but this particular fault would not be separable in a life test from poor construction of the filament.

The great problem of a life test is to keep the test lamps burning continuously at constant voltage over the interval of their useful life, that is, while their candle-power is reducing to 80 per cent of the initial rated candle-power. Even with the expedient of burning at 3.1 efficiency the test will still require from 15 to 20 days (360 to 450 hours), day in and day out. Automatic regulation enables us to obtain very reliable results.

The life test apparatus is shown in Fig. 8; it was constructed at the navy yard. There are six lamp banks, A (two are not shown): four banks are for lamps having the standard base (150 c. p., 32 c. p., and 16 c. p.) and can take 12 lamps each; a fifth bank can accommodate 48 1-candle-power instrument lamps, and a sixth bank, 48 5-candle-power instrument lamps. Each bank

has an adjustable resistance, by which the voltage of the bank can be adjusted to the voltage of the mains; hence, 80-, 110-, and 123-volt lamps can be tested at the same time. The difference in actual voltage of the lamps on the same bank for the same rated voltage are adjusted by inserting small pieces of resistance wire in series with the connection of the particular socket, the wiring

Fig. 8.—Compensating voltmeter and lamp banks.

being arranged to provide for it. These resistances give the lamps the voltage which produces an efficiency of 3.1 w. p. c. for each.

The voltage of the mains is kept constant by the automatic compensating voltmeter, *C*. The contact maker, *D*, is a long metal pointer which is pivoted at its upper end. At this pivot is fastened the armature of the electro-magnets and at such an angle with the main axis of the pointer that the armature will be

in the center line of the electro-magnets when the pointer is at its extreme throw to the left. The pointer is electrically connected to the current of the line through the circuits of the electro-magnets which are shunted off the main line. In its motion from side to side the contact maker, *D*, closes circuits at *E* and *F*, which send a current through either one or the other of the two solenoids, *G* and *H*, of a relay; these attract their armatures, *L*, *M*, to which are secured two springs carrying two carbon points each, to make the connection double pole. When these carbon points come in contact with two other carbons connected in the main line, the armature of the motor, *T*, is energized. The motor turns a screw bar on which is a slider, *S*, moving over the surface of a coil rheostat, *R*, having two coils in parallel, and which is placed in series with the main circuit. (The apparatus as reconstructed has four rheostats with four sliders.)

If the voltage of the line should get too low, a spring draws the pointer, *D*, to the right, making contact to the right; the solenoid, *G*, is energized, its armature is attracted and the carbon points make contact with those connected to the leads of the motor armature; the motor then moves the screw bar in that sense which will *reduce* the resistance in the rheostat, *R*. If the voltage of the line becomes too great the electro-magnets of the automatic voltmeter will attract their armature on the contact maker, *D*, against the tension of the spring, contact will be made to the left; the solenoid *H* will attract its armature, and the motor energizes to increase the resistance of the rheostat, *R*. The reversal of the motor is assured by separately exciting its field by shunts from the mains.

At *V* is a Bristol recording voltmeter; a clockwork mechanism revolves a card marked on its outer edge in hours for 24 hours. The voltmeter pointer of the instrument presses on this paper, tracing a line in ink; volts are measured radially along the curves from the center. This voltmeter keeps an accurate record of the action of the automatic voltmeter.

Although this automatic apparatus is connected for 8 hours of the day on a power circuit, whose voltage is much disturbed by throwing motors on and off, its performs its duty well under the adverse circumstances. From 5 p. m. to 8 a. m. the line is fed by the comparatively steady source of storage batteries. The compensating voltmeter has during this interval to compensate

for the small decrease of about one-half volt only; this ideal condition for the working of the compensating voltmeter is not available during the day owing to the necessity of charging the storage batteries. The sensibility of the compensating apparatus is such that it will operate on a change of two-tenths volt in either direction, insuring the great desideratum of a life test, steady voltage.

When selected for life test each lamp is given a serial or reference number, which is marked on the label. The number is also scratched on the brass base. This number identifies the lamp upon the records and throughout the test.

One lamp of each lot is laid aside to be used at the end of the test for comparing the blackening upon the inside of the bulbs.

Each lamp put on life test is first tested for vacuum.

The voltage of the lamps selected for life test is brought to that value at which the lamp burns at 3.1 watts per mean horizontal candle-power. Throughout the life test each lamp is burned at the particular voltage which was required to give 3.1 w. p. c. initially.

The voltage to be used for an efficiency of 3.1 w. p. c. is obtained experimentally; it can be calculated approximately by the compound proportion, the total watts at the efficiency of the design as determined by the photometer test compared with the total watts at 3.1 w. p. c., the rated candle-power compared with that at 3.1 w. p. c., and the voltage as determined by the photometer test compared with the unkown, or that to be maintained for an efficiency at 3.1 w. p. c. In practice the required voltage is picked out from a previously constructed curve in per cent, but the curve must be made on a large scale to obtain the fractions of per cent incident to variations of one-tenth of a volt.

As before cited, photometer tests are made after a run of 25, 50, 75, and 100 hours and after every 100 hours thereafter until the candle-power has decreased to 80 per cent of its initial candle-power. The periods should be kept as close to 25, 50, 75, and 100 hours as possible. In case any run exceeds, 25, 50, 75, or 100 hours as the case may be, the next period is to be that much shorter so that no time accumulates. The average value of the candle-hour performance of the lamps subjected to life test must not be less than the amount shown in column 8, Table 2.

Adjust the compensating voltmeter and calibrate all other

apparatus to be used during the life test. Be sure that the adjustment and operation is correct and make a trial run on dummy lamps for a day and a night before starting the test run. This will remove the variation due to heating of the coils of the compensating voltmeter and other apparatus. When a lamp burns out ascertain if the difficulty is with the filament of the lamp before removing it from the rack. Note and record the time at which the lamp burned out, and if possible the cause. Save the lamp for a print to show blackening and location of defect in filament.

A new chart is dated and put in the Bristol recording voltmeter each day; the clock attachment being wound up at the same time. From time to time (preferably once a day) the recording voltmeter is compared with the standards. By means of an auxiliary resistance in series with the recording instrument, its calibration can be changed to conform with that of the standard when necessary.

As charts are taken off they are again dated and upon them a note is entered indicating the lamps burning during the time represented by the record.

The Bristol instrument is especially intended to record, by an irregularity in the curve, the elapsed time of any break in the circuit such as would be caused by a fuse blowing out or the operation of any one of the automatic devices for opening the circuit.

In case a lamp burns out during the night the potential rises owing to the change in current in the resistance coils, and a small irregularity will be noticed on the line of the Bristol recording voltmeter which records the exact time of the burning out.

The voltage of the lamps under test should be often checked, and adjustment made upon the rheostats when necessary.

The lamp banks are made up of spring sockets so that the life test can be run with lamp filaments at any horizontal angle. As the test is now made the loop of the filament lays flat so that the drooping effect may be observed. Spring sockets also give a means of testing for the strength of cementing of the base of a lamp which must stand screwing up hard without breaking the base away from the bulb.

Heating of the clamp where the filament joins the platinum

leading-in wires is a defect which is to be carefully watched during a life test.

The charts should be kept to constitute a complete check upon the "Time Log." The entries in the time log should be made each morning and evening and should contain notes of the condition of the test at the time and also a record of the times of opening and closing the circuit. The log is intended to be a record of the time the lamps have burned. If the circuit should be opened during the night the entry would be made from the chart of the recording voltmeter, but under no other circumstances should the voltmeter chart be used for making entries in the time log.

Voltmeters are kept in the lamp circuit during the entire run. Besides this, the photometer instruments consisting of voltmeter and ammeter are reserved for this work only. These instruments are calibrated at regular intervals and always before taking the photometer test at the 25, 50, 75, and 100 hour intervals.

Method of Recording and Reporting Tests.

As the photometer tests are made the data are recorded. Each of the separate tests is averaged and entered up in the resumé. The resumé is intended to show the results of the test and is made up to represent the average of the lot of lamps under test.

Lamps.—The test is started with a certain number of lamps, and as these burn out the actual number left burning is recorded as indicated.

Average c. p.—The initial is taken as 100 per cent, and the actual is expressed in terms of it. The candle-power is the mean horizontal candle-power as measured by the photometer while the lamp rotates at 180 r. p. m.

Average w. p. c.—(Average watts per candle when running at the current and voltage determined by photometer.) The initial is taken as 100 per cent and the actual is expressed in terms of it.

The candle-hour performance of the lamps is considered as the sum of the candle hours given during each of the observed intervals, and up to that time when the lamp shall have burned out or shall have fallen to 80 per cent of its test candle-power.

Resistance.—The initial is taken at 100 per cent and is from

the readings of current and voltage of lamps during the preliminary photometer run. The actual is computed from the data recorded.

From the resumé data is taken to plot the following curves (Fig. 9):

(a) With time and c. p. (average) as co-ordinates.

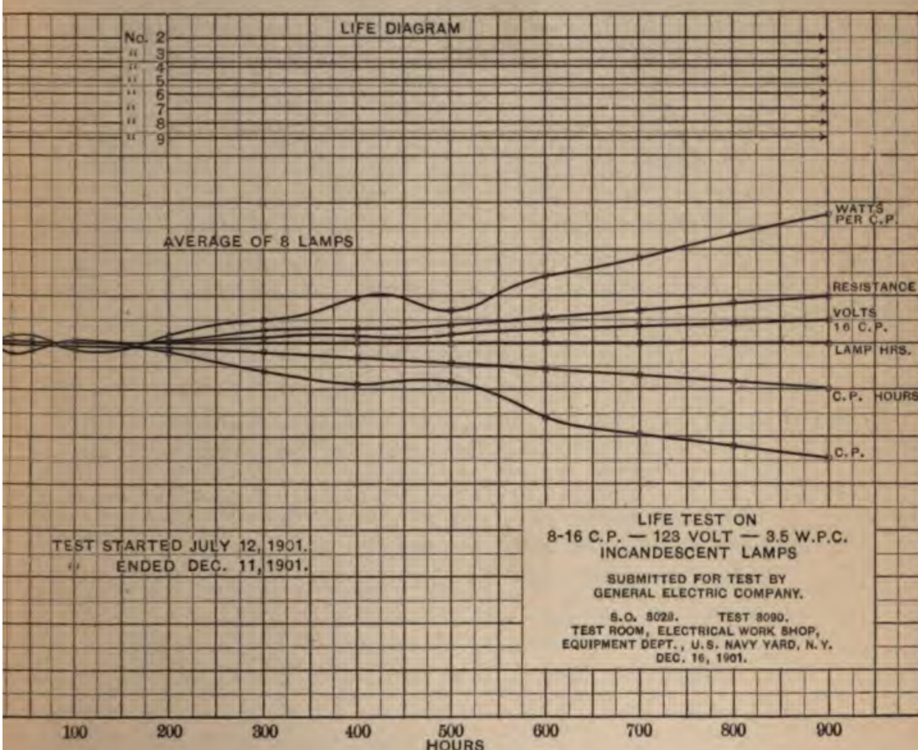


FIG. 9.—Curves of performance on life test.

(b) With time and volts per rated c. p. co-ordinates.

(c) With time and w. p. c. (average) co-ordinates.

(d) With time and resistance (average) co-ordinates.

(e) With time and lamp hours (total) co-ordinates.

(f) With time and c. p. hours (total) co-ordinates.

The length of time a lamp burns is represented by the length of a line drawn parallel to the time co-ordinate, one time to represent one lamp.

It will be noted in Fig. 9 that the candle-power developed for the first 50 hours or so is greater than that for which the lamp is designed; this result is characteristic of all life tests and is the occasion for the prescription of 3 per cent in specifications.

After completion of the test all the lamps are mounted (or a selected representative number) with the one which was laid aside at the start, in receptacles on a block and a photograph made through them, preferably using an arc or a search-light for a source of light as the definition from this light is sharper and the defects in the filament and glass are better shown.

The lamp that was set aside should be mounted in the center and those that ran the longest disposed equally on each side; that that burned out first being at the ends.

The Target Diagram.—The Target, or "shotgun," diagram, when used in connection with the curves of Fig. 9, shows at a glance the results of the photometer and life tests of the test lamps. The diagram, Fig. 10, is constructed with candle-power and total watts as the co-ordinates forming a rectangle. The diagonals are the efficiency limits based on a mean rating of 3.5 w. p. c. As the upper left-hand and lower right-hand triangles are outside the prescribed limits the diagram represented by the contour line is really that used for reference.

The upper large black dot represents the mean for all the lamps as tested by photometer before the life test.

Each lamp of the test lot is plotted on the diagram by its serial test number in accordance with the results obtained on photometer test, and again from photometer results after life test; the same lamp in each case is then connected on the diagram by a dotted line to show individual performance, the slopes of these lines should evidently be the same. A mean position is also plotted which is derived from results for all the lamps, as in the case of the photometer test. This mean shows the general characteristics of the whole test lot submitted and also the particular feature in which the lot is lacking.

In order to obtain intelligent results from the diagram care should be taken *not to construct it from a selected lot of lamps sent by a manufacturer;* the test lot of the actual delivery is the only good guide of performance, as selected lamps could be so picked out as to show quite different results from those determined by the test of the delivery.

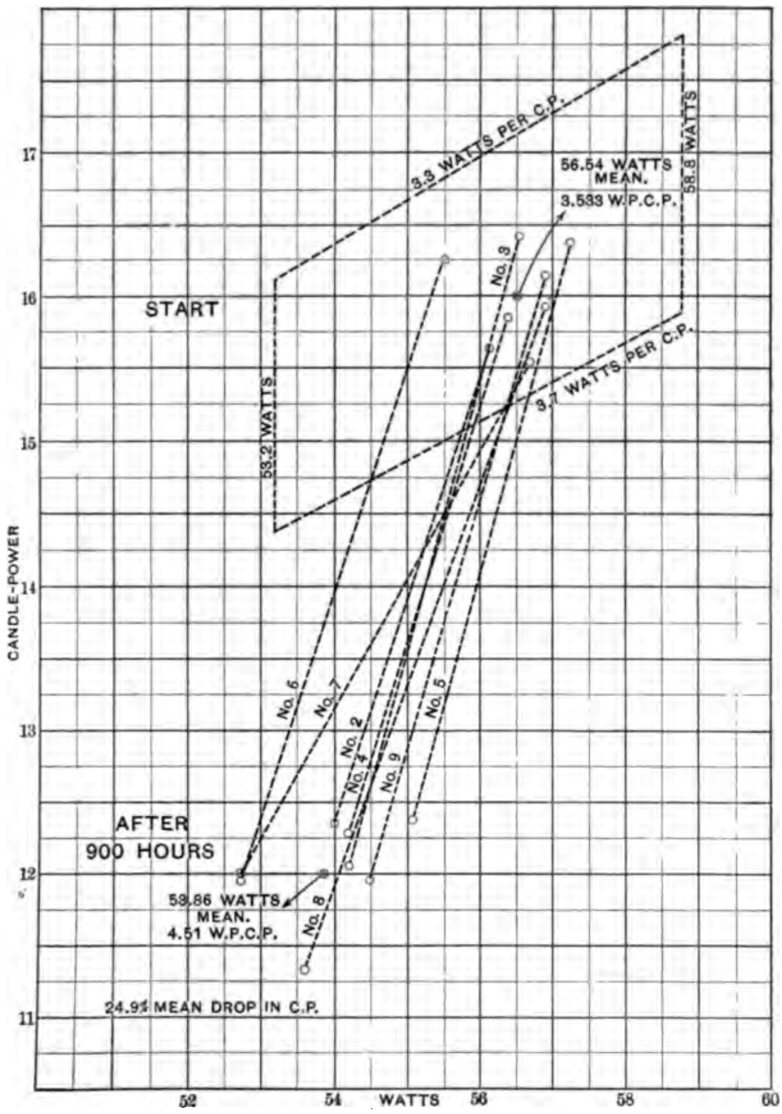


FIG. 10.—The target diagram.

CHAPTER II.

ARC LAMPS AND SEARCH-LIGHTS.

The feature of arc lamp lighting is the great amount of light emitted from a single fixture, affording a decided advantage when large spaces are to be lighted whose height, or general use, renders the total required installation of incandescent lights difficult, insufficient and expensive in comparison; the spaces usually so lighted are fire rooms and engine rooms, and the arc lamps furnished a ship are on the basis of one lamp for each fire room and one lamp forward and abaft each main engine.

Arc lamps give very efficient lighting over coal barges when taking coal at night.

The type of arc lamp heretofore supplied, and known as the "miniature arc lamp," has been superseded by a commercial type commonly used for interior lighting and known as the "parallel rod, edgewise wound, direct current, enclosed arc" lamp. It is shown in Fig. 11. It operates at 4½ amperes and is adjustable for 80, 110, and 125 volts.

The advantages of the enclosed arc type over the open arc are: first, it can be run off the mains in multiple similarly to an incandescent lamp; second, it requires less trimming (putting in new carbons) for, while an open arc lamp will require the renewal of at least its positive carbon after burning for but from 12 to 14 hours, that of the enclosed arc will not require renewal under from 100 to 175 hours. The carbons of the lamp shown in Fig. 11, having a closed-base enclosing globe, will burn from 125 to 150 hours.

The mechanism is protected from dust, etc., by a bronzed sheet copper casing (Fig. 11), which is attached to the lower inner edge of the cap (at the top) by hook bayonet joints and held by set screws. To the lower edge of the casing is secured the clear glass outer globe which is protected by a guard, or cage, also secured to the casing. By loosening the thumb screws which hold the casing to the cap, and disengaging the bayonet joint, the casing together with guard and globe can be taken off clear of the inner (enclosing) globe and the mechanism.

The enclosing globe is of opalescent glass, is closed at the bottom and is held to the disc framing of the mechanism by

screws under the globe flange. Its office is to exclude air from the carbons, having the general effect of increasing the voltage required to maintain the arc; for, while open arcs are generally

FIG. 11.

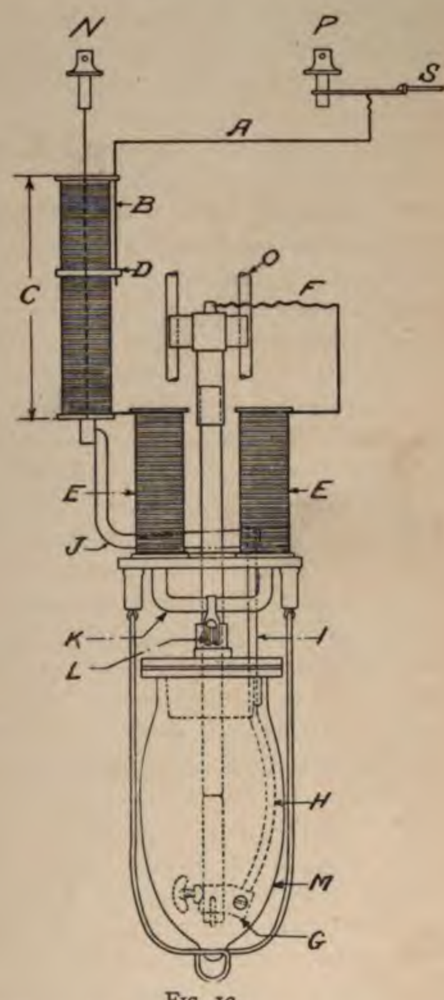


FIG. 12.

FIG. 11.—Arc lamp, Form 12, General Electric Company.
FIG. 12.—Mechanism of the Form 12 arc lamp.

maintained at approximately 50 volts, the enclosed arc requires an average of approximately 85 volts; this, of course, represents

a loss of energy in comparison, for as two lamps in series could be run on a 110-volt circuit with a loss of but 60 watts for both, the enclosed arc system represents a loss of 180 watts for the single lamp; the convenience of branching off the enclosed arc type in multiple, its softer light and the material reduction in labor of replacing carbons has, however, caused it to largely supersede the open arc for street lighting and very generally for interiors.

The mechanism is shown in Fig. 12.

The current entering the electrode *P* reaches the slack positive wire *A* through the switch *S;* this wire is connected to a brass rod *B* which runs in a guide hole of the top of the spool of the rheostat *C;* on this rheostat is a ring or movable contact *D,* which can be set at any proper place on the rheostat *C* necessary to give that voltage which will give best working of the lamp; its effect is to connect the positive wire to that point of the resistance which will cut down the potential of the line, between the positive terminal *P* and the negative terminal *N,* to that potential at which the lamp is to operate; it is essential that the ring *D* shall be adjusted and set by the lamp makers in conformity with the voltage of the customer's supply line, and that it shall not be changed thereafter except by experts.

The rheostat *C* is made of bare, flat wire or ribbon and is wound on edge, each layer being insulated by a non-inflammable material; this, and the similar construction of the magnet windings, occasions the designation "edgewise wound."

After passing through the flat windings of the rheostat *C,* below the movable contact *D,* the current passes to the windings of the two electro-magnets *E,* and thence by a slack wire *F* to the holder of the positive (upper) carbon *I.* The current then passes (by contact, or arc) to the negative carbon, thence to the clamp *G* and metal frame *H,* which holds the negative carbon, to a brass rod *I,* extending up back of the magnets, to a curved cross rod *J* that leads under the center of the rheostat *C.* From this point a straight connection leads to the negative terminal clear of, and through the center of, the rheostat.

The operation is: The entering current through *P, A, D,* and the rheostat *C*—finally reaching *N*—energizes the two electro-magnets *E;* these magnets draw up a horseshoe-shaped plunger *K,* which has a holder with bell-crank clamp *L;* this clamp grips

the positive carbon as long as K is attracted into the magnet core and only releases it when resting on the disc frame which carries the enclosing globe M. The action of the plunger thus strikes the arc and starts the lamp. As the carbons burn away, the resistance across the arc increases, decreasing the current in the windings of the electro-magnets and hence the lifting power of those magnets; the resulting effect is that the positive carbon is lowered until the magnets hold it in proper relation to the resistance; that is, the magnets automatically adjust the distance to be maintained between the two carbons for steady burning and steady light. The guide rods O are in reality attached to the plunger K through the center of the electro-magnets, thus centering the plunger and keeping the axes of the positive and negative carbons in line; they are connected to a small dash pot (not shown) containing air only, which cushions any shock which might occur from a sudden failure of the current in the magnets and the consequent dropping of the plunger K.

When the switch S is opened the positive carbon descends slowly until the clamp L strikes the disc frame; the clamp then releases the positive carbon, which descends to rest on the negative, making an actual contact which is the necessary condition for the next starting up.

General Directions.—Only high grade solid carbons should be used in the lamp; the dimensions of the positive are 12 x ½ inch, and of the negative, 5 x ½ inch.

After unpacking a lamp, remove its casing, which is supported at the top by a bayonet joint. Loosen the thumb screw at the side of the top cap, raise the casing slightly and turn it to the left until it can be lowered. Take out all wedges and packing from the mechanism. Brush out any dust that may have accumulated, and examine the mechanism for loosened parts. Be sure that the movable parts work freely. Then replace the casing and the lamp will be ready for operation.

The lamps are usually installed on board ship by connecting to a switch and receptacle through a length of double conductor, plain, and the ordinary attachment plug; the use of the switch S (Fig. 12) is therefore not necessary; the adjoining junction box contains the fuse for the lead. *The binding post on the switch side of the lamp is positive and the attachment plug must be so entered into the clip of the receptacle as to insure this*

polarity; this is best accomplished by marking the contacts o the plug plus and minus and scribing the corresponding mark on the receptacle; if there is doubt as to which side is positive insert the plug into the receptacle, let the lamp burn a few minutes and then switch off; the upper (positive) carbon should remain red hot longer than the lower (negative)—if the lower carbon remains red hot longer, reverse the plug.

The lamp should never be used without the enclosing globe, which excludes air from the arc. Closed base enclosing globes must rest squarely against the machined surface of the stationary cap. The number of hours the lamp will burn at one trimming depends largely upon keeping the globe tight and excluding the air.

As carbons vary somewhat in diameter, use only those of the dimensions specified. They should pass freely through the enclosing globe cap, for any friction at this point will prevent the proper operation of the lamp. The carbons must be smooth—sandpaper them if necessary, to remove small bunches of blisters.

To insure proper electrical connection to the positive carbon, it must be well inserted in the spring carbon-holder. Inserting carbons is facilitated by bevelling their ends. Better light will be obtained if the enclosing globe is cleaned thoroughly at each trimming.

Carbons are usually supplied in 12-inch lengths, the negative carbon being advantageously derived from the remainder of the positive after some use. Spare carbons should be stowed in moisture proof tins and care should be taken that they do not absorb oil.

Never use oil in the dash pot or on any part of the mechanism.

Inspection of Arc Lamps.

Mechanical Construction.—The general workmanship in appearance, strength and adequate sufficiency of the various parts and the mechanism is rather a matter of comparison for the many details, comprising in each lamp some 36 parts apart from assembling machine screws. Principal points are as follows:

1. The overall dimensions from inner edge of top of hook to extreme base of guard not to exceed 27½ inches; maximum allowable width at any part 8½ inches; maximum weight, 23 pounds.

The dimensions should be a minimum on account of the character of the locations for which the type of lamp is intended; the locations forward and abaft main engines is an especially contracted space; the limiting dimensions are those which are readily met by commercial types of construction.

2. The design of the lamp and its operating parts must be such as to adapt it for use in engine and fire rooms of naval vessels.

This specification is to be considered with reference to the effect of the rolling, pitching and vibration of the vessel; the capability of continued operation when subjected to the moisture, dirt and oil incident to engine and fire rooms; and its capability of continued operation when exposed to weather, an experience to which the lamp will be subjected when used for lighting over coal barges when working at night. The determination of these matters rests mainly on the tightness of the outer and enclosing globe and the close assembly of the casing.

3. The top of the case is to be in one piece to form a watershed, and to have an insulated hook for suspension.

The cap is usually so designed, note particularly that the suspension hook is insulated.

4. The case enclosing the operating mechanism shall be susceptible of ready removal, and replacement.

The desirable feature should go farther than this and include the removal and replacement of the casing, outer globe and guard without disassembly of these parts; the proper method is explained in the description. This is not to be construed as meaning that the casing must be removed when the carbons are to be renewed; this is provided for in the next item.

5. To be fitted with a strong guard, bronze finish, capable of ready removal without the use of tools, and fitted with chains which will permit the dropping of the guard far enough below the enclosing globe that this globe can be conveniently removed in trimming.

6. The outer globe must be capable of being removed with the guard.

This does not preclude that they shall be separate, that is, it is not necessary that they be attached to the same ring with hinge design, etc. The globe requires to be separated for the cleaning necessary, at least, whenever the lamp is trimmed.

7. The lamp is to be designed to take at least a 10-inch positive carbon. The usual carbon is 12-inch.

8. The outer and enclosing globe are to conform to the official drawing, but are acceptable if interchangeable with the design of that drawing.

The enclosing globe is specified to be of the light opal type; it is advisable that the opalescence be not too obstructive of the candle-power emissivity of the lamp.

9. Resistance material of the rheostat must be non-corrosive; the mounting must insure against sagging from excessive heating, crossed grounds or short circuits. Means for readily adjusting the resistance must be provided.

The resistance is designed for adjustment over the range of 80, 110, and 125 volts of the supply line, but is not intended to be altered after once being adjusted for the voltage used in the particular ship.

10. Switches are not required, but if they are fitted they must be of the self-contained lever type, and accessible by use of a stick from the deck below.

A ring or hook must be a part of the design, to afford a means of suspension. Terminals for the line are to be fitted at the top and marked for polarity.

Electrical Qualifications and Test.—The lamp after unpacking and examination as to mechanical matters is connected up to a 80, 110, or 125 volt circuit, as the particular delivery may be specified, and the connections are traced to determine that the polarity as marked on the terminals is that of the connections. The cold drop of the magnet windings (for heat rise, see test of Generators) is then taken and the temperature of the resistance and casing is taken by thermometers, covering the bulbs with cotton. The current is then switched in and the lamp run for four hours, when the hot drop of the magnet windings is taken, and the temperature of the resistance and casing as before. The temperature of the air is noted half-hourly during test.

The permissible heat rise of the magnet windings is 60 degrees centigrade. There is no restriction as to the heat of the resistance or casing. (The low limit of 60 degrees is necessitated by the hot locations in which the lamp is to be used.)

2. While still hot a high potential test of 1000 volts (see test of Generating Sets) is made for one minute between the current

carrying parts and the frame; these include the lead from the positive terminal; the windings of the resistance; the winding of the magnets; positive carbon holder; negative carbon holder and frame and rod attachment leading to the connection at the base of the resistance; and the negative lead.

3. Test is then made of the adaptability of the resistance for adjustment for 80, 110, and 125-volt circuits by adjusting the movable contact on the resistance; the greater the voltage of the supply the greater the resistance to be introduced, and the higher the contact must be clamped on the rheostat. As lamp constructions differ somewhat the point at which, for a given voltage in line supply, the lamp operates best must be selected; lowering the contact clip increases the arc voltage.

4. During the four hour run an ammeter is kept in the lamp circuit and the operation of the current regulation, by the magnets noted. The observations should be frequent and the current regulation must be within five per cent.

5. Observations must be made during the four-hour test that the arc is steady and free of jump and flaming; the current variations (four above) are particularly to be noted if jump and flaming occurs (it is, however, more a matter of quality of carbons than of lamp operation).

6. A life test—a test of the carbons—is next made, the new carbons being allowed to burn continuously until the positive carbon is consumed. Tests usually show about 130 hours. General observations of the operation of the lamp are made during this interval.

7. The lamp must automatically cut the lamp out of circuit when the carbons are consumed.

If a life test is not made, this is tested by putting in a short positive carbon, and running the lamp until the carbon burns away.

Search-Lights.

The varieties of projector usually met with in the service are of the manufacture of the General Electric Company or of the Schuckert Company. The sizes, rated by diameter of mirror, are 13-inch, 18-inch, 24-inch, and 30-inch; two 36-inch have been in use, and one 60-inch size has been installed.

The varieties (General Electric and Schuckert) have much in common, though differing in details; as a comparison in service

experience, preference is often given to the General Electric Company's type of lamp on account of its good service and simplicity; and to the Schuckert Company's drum, or barrel, by reason of the opportunity of closure of the front of its drum by a shutter, or "Iris Blind," a convenient and advantageous arrangement for search-light exercise, as the focusing and adjustments may be made ready before the signal for exercise; also, at the expiration, the light can be masked and then lumed off without showing the glow; another advantage for navigating purposes is the facility of masking or using the light as required without delays incident to focusing, switching, etc. This is especially an advantage in torpedo-boat destroyers whose search-light must be placed low down, and whose use has a blinding effect on the officer at the conn, whether on the bridge or near the wheel.

[NOTE 3.—The General Electric Company has recently designed a shutter. It consists essentially of radial rods across the aperture of the drum to which light blades are attached on each side: the rods move together through gearing throwing the plane of the blades parallel with the beam when open: the device makes good closure against escape of light when the blades are across the beam.]

General Electric Company's Projector.

There are two types of this projector manufactured by the General Electric Company, viz.: the "Electrical Control" and the "Hand Control."

Both types are alike in outward appearance, but the former type in addition to the usual electrical connections and training mechanism, contains two shunt motors, each with their train of gears. This type, in addition, is provided with a controller, controller receptacle and a flexible cable to connect the controller to the receptacle. The controller, motors, etc., however, are not now generally installed. The 30-inch size, fitted for electrical control, is shown in Fig. 13.

[NOTE 4.—The electrically controlled projector, by reason of its convenient operation from advantageous locations for the operator and especially when the projector is installed in tops, is probably again to be introduced: the difficulties occasioning its removal from service were with the controller, from burning out and corrosion of the enclosed resistances, but incident to the lack of care on the part of personnel rather than to general inherent defects, the principal of which was that the interior was not well water-tighted; in the newer types of controller the defect has been remedied.]

he projector consists essentially of a base, fork, drum, mirror, rator and magnet, automatic and hand feed lamp.

he base consists of a casting drilled at the bottom to bolt

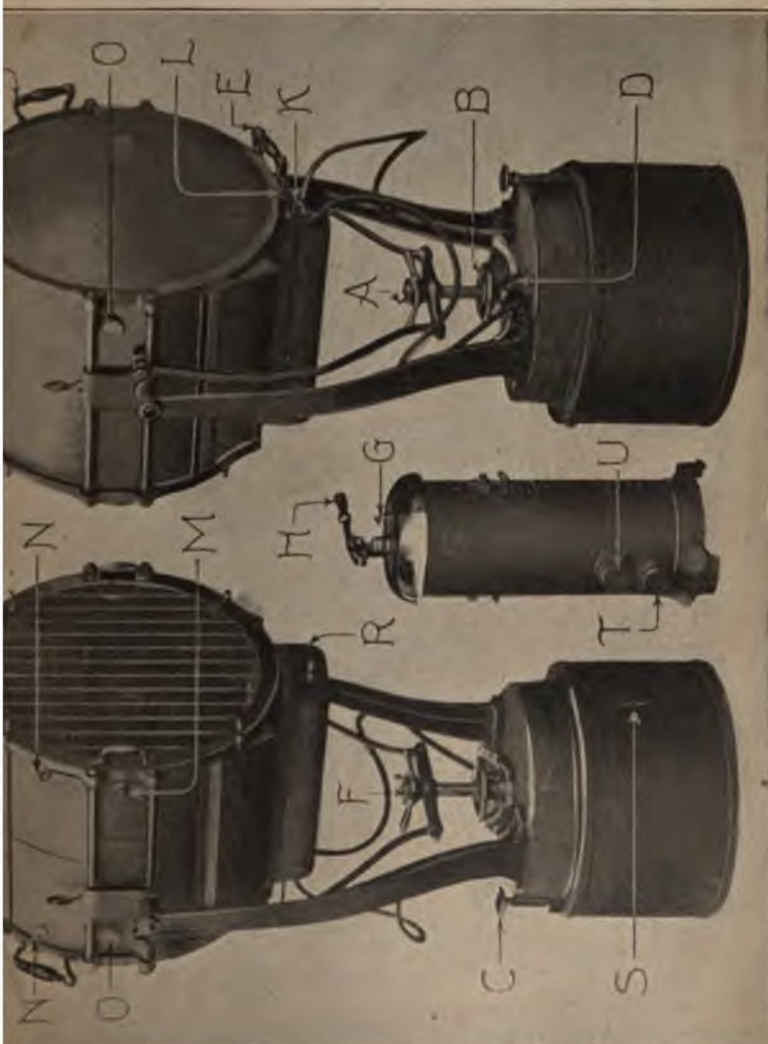


FIG. 13.—30-inch projector, General Electric Company.

he deck and to receive the line wires, which wires connect he lower terminal of a double-pole switch secured to the ; the upper surface of the base has a track ring for the

fork and drum to revolve upon, and to it are secured two insulated plungers with springs which act as conductors for the two leads which connect to the upper terminals of the double-pole switch.

The fork which supports the drum is composed of three castings; two arms and a turntable.

The upper end of the fork is fitted with bearings in which the drum trunnions work. The lower ends of the fork are bolted to the turntable. On the underside of the turntable the rollers are secured, which bear on the tracks of the base, and spring plungers in the base make electrical connection to two contact rings on the under side of the top of the turntable. From each of the contact rings a wire cable is led up to the lamp, and is secured midway, on the inner side of each arm of the fork by a brass clamp (see Fig. 13). The turntable of the electrically (changeable to hand-control) controlled projector contains a spindle surmounted by a cross-head with a special locking device of which: *A* is a hand star wheel for slow vertical movement; *B* is a wheel for throwing out a split nut, and is used for connecting or disconnecting the drum from the base mechanism; *D* is a hand star wheel for clamping the turntable to the center pin for engaging the electrical control. In the turntable of the projector having hand control only, all the gearing is omitted and only the hand star nut for clamping the horizontal movement is retained; the vertical movement being controlled by a hand star wheel on one of the arms of the fork and a quadrant fitted to one of the trunnions on the drum.

The drum consists of a cylinder, ventilators, mirror, front door frames, back cover and handles.

The cylinder is of sheet metal provided with three ventilators, two on the lower part of the drum to admit air; and one on top of the drum to allow the hot air to escape, and being so designed as to prevent entrance of wind and rain, or the escape and discovery of light; if to be located within 30 feet of the compass, the metal of the barrel and the securing rods should be specified to be of a non-magnetizable metal; experience in service shows this to be mandatory.

On one side of the upper ventilators is a focussing peep sight *P*, fitted with a lens and an enameled glass plate; on the latter the image of the carbons is reflected when the lamp is in operation and focus. A colored peep sight *O* is situated on each

side of the drum, which permits of viewing the arc without dazzling the eye.

A trunnion is secured on each side of the drum, and two eye bolts, shown, one on each side, are installed on the trunnion blocks to facilitate transportation.

The mirror frame is of brass, lined with asbestos, and is fitted at the back with equally spaced springs which hold the mirror in place, allow for expansion due to heating and provide for flexibility under shock of concussion. It is secured to one end of the drum and protection to the frame and mirror against mechanical injury is provided by a metal cover secured to the barrel.

The mirror is of glass ground to parabolic curvature, silvered on the back, the silvering being protected by a close covering of hard paint. The mirror frame is designed to take either Mangin or parabolic mirrors; both types are in use, but for some time past the practice has been to use the parabolic mirror only, it having the advantage of less noticeable, and therefore confusing penumbra as compared with concave mirror types, and greater effective aperture as compared with the Mangin; its distinct *apparent* advantage (as compared with the concave mirror) is that it lights up the foreground better and, as we are accustomed to outlining objects by their surroundings, the target is brought out with more sharpness and distinctness of outline.

The drum contains the mirror, obturator, drum slide contacts and the horizontal lamp. It has two handles *E* which serve to facilitate its manipulation when rapidity of movement is required. Two doors, *M* and *N*, are fitted to afford access to the carbons and the interior generally.

Front Door.—The opening of the barrel is closed by a door consisting of a ring having two handles (shown) and glazed with strips of plate glass. The use of the strips is more convenient and is more economical in affording a readier means of renewal after breakage by concussion, etc., than would be practicable for a solid pane.

The obturator, Fig. 14 (colloquially "shutter" but from which it should be distinguished), is suspended by a bracket as near to the arc as possible. It consists of an electro-magnet (magnetized by the current flowing through the carbons) and two semicircular brass shutters whose outer edges are hinged

to a bracket; a clamp serves to hold the shutters in position when closed. The object of the obturator is to cut off those rays of light which would otherwise proceed in a cone directly from the arc without being reflected by the mirror into a parallel beam. The magnet consists of a broken ring of soft iron, curved to surround the arc on all sides except the top; its office is to counteract the tendency of the arc to force upward—thus burning away the carbon at the top and forming an imperfect and inefficient crater—a tendency which is created by the hot air currents rising through the barrel. The magnet can be rotated on its horizontal axis, this device contemplating its use to align the arc should it tend to the side as well as the top, a condition sometimes arising from imperfection in the carbons.

FIG. 14.—Obturator and magnet.

The drum slide contacts are secured to the inner lower part of the drum and to these contacts the cables leading from the contact rings are connected.

The controller, Fig. 13, is a sheet brass cylindrical cover attached to a composition base, with handles at the side for transportation. The latest type is much shorter than that of the figure and is fitted to be mounted on a bracket, or as convenient. Near the base is a coupling *T* fitted with recurved springs for electrical connection to the coupling attached to the controller cable. The resistance coils are in the interior of the case and ventilation is afforded around the rim of the cap. The controller (and hence the motors in the base of the projector) can be thrown in and out of circuit by the switch *G*. The handle *H* has a vertical plunger which makes contact with the motor supply lines (*G* being closed) to accomplish elevation and depression of the barrel and its motion to the right and left; the

device admits of simultaneous operation of elevation combined with a motion to the right or to the left as desired, or of depres-

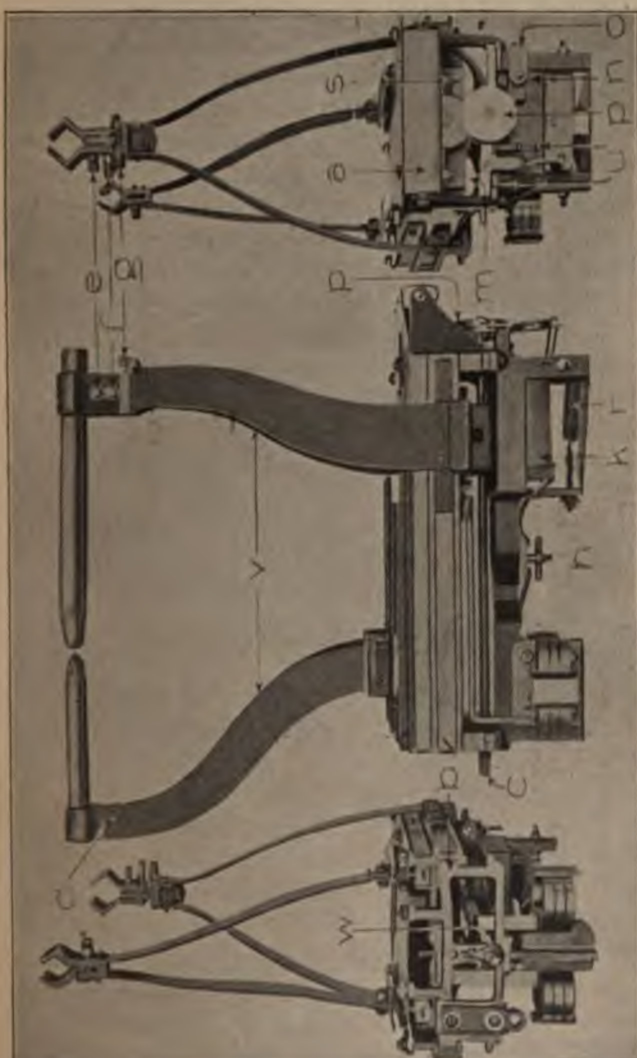


FIG. 15.—Lamp for 30-inch projector, General Electric Company.

sion combined with a motion to right or to the left; to elevate, the handle is raised; to depress it is pushed down; to move the barrel to the right the handle is moved to the operator's right, to

move to the left, to the operator's left; to operate vertically and in azimuth at the same time, first move the handle for elevation (or depression) and, holding it in that position, move to the right or left; releasing the handle for any position attained leaves the barrel pointing in that position. The maximum permissible elevation is usually 40 degrees, the maximum depression 20 degrees; a train of the complete circle is practicable. The tube *U* just above that for the controller cable is capped and contains the fuse for the supply line of the controller.

The lamp, Fig. 15, is of the horizontal, automatic, ratchet feed focussing, type; it is remarkably compact, simple, and efficient in throwing the greatest practicable amount of effective light on the mirror. The obturator cuts off the direct rays and the magnet centers the crater to the center line of the mirror. The carbon carriers are designed for vertical and horizontal adjustment of the carbons; the automatic feed controls the crater at the focus until the carbons are consumed. The principal parts are described in connection with the operation of the lamp under automatic feed, as follows:

When the main switch *S* (Fig. 13) is closed, the current enters by the positive connection to the insulated plunger on the inner top of the base, thence to the contact ring within the turntable, and by the positive wire up to the drum slide contact within the drum; before closing this switch the automatic feed switch *h* (Fig. 15) must be closed, and the carbons set about one-eighth inch apart by a socket wrench shipped on the square post *c* of the screw bar.

The main current enters the lamp by the positive contact spring (shown in three leaves and a contact plate below *c*), insulated from the frame, which is connected to the winding of the series, or striking arc, magnet *m*. Since, on closing the main switch, no current is passing, the dead resistance of the rheostat has no effect in cutting down the voltage to that required for usual operation of the arc; and, the resistance of separation of the carbons, one-eighth inch, being small, the voltage across the carbons at the instant of closing the main switch is approximately that at the switchboard, hence the striking arc magnet receives a large excess current, attracts its armature, which (being attached to the upper screw bar) moves the carbon-holder, forming ("striking") the arc; the arc having been struck, the dead re-

sistance of the rheostat—on passage of the current—cuts down the voltage to the operating voltage of the arc, about 50 volts, which voltage value is insufficient to maintain the attraction of the striking arc magnet for its armature; the armature is released, and the lamp thereafter controls the length of the arc by the shunt feed; the release of the armature of the striking arc magnet does not operate to approach the carbons by reason of lost motion of the nut of the screw-bar in its guide.

From the winding of the striking arc magnet *m* the current leads direct to the frame of the lamp, the whole lamp being insulated from the drum. From the frame the positive carbon (the larger in the figure) receives current directly through the carbon-holder; thence the current crosses the arc to the negative carbon, and by its holder and a flexible connection to the negative lamp contact spring; thence to the drum sliding contact, wire connection, contact ring in turntable, a plunger, and flexible lead to the negative terminal of the switch *S* (Fig. 13). As the carbons (principally the positive) burn away the arc becomes attenuated, diminishing the luminosity of the crater, or the arc might break; to obviate this and trim the arc to proper length the automatic shunt feed is introduced consisting of the clutch magnet *K* and its operating parts.

The path of the shunt current is from the base of the lamp, through the contact of the circuit breaker *O*, through the clutch magnet *K* and switch *h* to the negative lamp contact spring. After starting, the carbons being apart, the current flows only through the clutch magnet *K* and attracts the armature *n*, but in doing so, the circuit is opened at the circuit breaker and the armature returns to its original position, being pulled back by the regulating spring *r*, reclosing the circuit; the armature is again attracted and this movement will take place as long as the carbons are too far apart. It results from the fact that the efficient arc is maintained at from 47 to 50 volts; as long as the voltage, due to increased length of arc, does not attain a value of greater than 50 to 51 volts the armature of the clutch magnet will not be attracted and the feeding system remains inactive.

The movement of the armature turns the lamp feeding screws by means of the clutch *p*, to which it is connected, and at each stroke brings the points of the carbons nearer to one another; should the carbons come in contact, the main current passes

through them, and through the arc striking magnet *m*, attracting its armature, and again striking the arc—this is, however, rare.

This armature *s* is mounted on the upper feeding screw and carries it along in its movement until the carbons are sufficiently separated to start the arc. After the arc is started, the clutch magnet *k* being in multiple with it, will be traversed by a current proportional to the drop of potential across the arc. As the carbons burn away this drop increases gradually and the current through the clutch magnet *k* finally becomes strong enough to overcome the tension of the spring *r* and attract the armature *n* bringing the carbons nearer together. The regulation of the lamp is therefore adjusted by the tension of the spring *r*. If by accident or careless handling of the lamp the adjustment should be disarranged, the lamp would not burn at the right voltage at the arc; a voltmeter should be connected across the terminals of the lamp, and if the voltage is below the normal, tighten the spring *r* until the adjustment is right; tightening the spring increases the length of the arc and consequently the voltage; loosening the spring shortens the arc and decreases the voltage.

This adjustment should not be disturbed unless in case of actual necessity.

Operation by Hand Feed.—First see that the automatic switch *h* (Fig. 15) is open and the carbons apart before closing the switch *S* (Fig. 13) on the projector base.

To start the lamp, bring the carbons together and immediately separate them to about ⅛-inch. The carbons should be fed every half minute by means of the crank-handled socket wrench on the post (or through the tube *L*, Fig. 13) at the back of the projector. Start feeding when the length of the arc is approximately about ¼-inch.

To Place the Lamp in the Drum.—Firmly clamp the wheel *B* (Fig. 13); if the front door is in place remove and place it in box. If the lamp is carboned, remove the carbons. Open the obturator shutters and turn the magnet piece until the opening points downward. Take hold of the lamp by the handle *a* (Fig. 15) and casting *b* (never by the carbon carriers) and let the back end of the lamp rest on the drum slides, still holding the front end up, push until the lamp falls into the two slots in the slides, then lower the front end into place. Press the lamp against the focussing screw and turn the wheel until the lamp

is caught and brought nearly in focus, *i. e.*, when the front end of the lamp is level with the white line marked on the drum. The sliding door can be opened to facilitate the operation. The magnet piece is to be turned down before placing the carbons.

To Focus the Lamp Whilst Burning.—It is not necessary to elevate or depress the beam for this purpose, though some operators regard it as more convenient; the vertical motion in this case should be elevation, and never more than 40 degrees; 25 degrees is a good and sufficient angle.

Move the lamp horizontally by means of the focussing screw *K* (Fig. 13), nearer to or away from the mirror until the beam of light has its *minimum divergence*, which for the parabolic mirror is about 3 degrees; if the beam diverges move the lamp from the mirror, if it converges move the lamp towards the mirror.

To Place the Carbons.—Separate the carbon carriers *v* (Fig. 15) as far as possible by means of the brass crank-handled socket wrench, which is kept in the tool box; insert the wrench in the tube at the back of the drum and push it in until it fits on the square head of the lamp feeding screw *c*, then turn it in the proper direction for separating the carbon carriers.

Place the negative carbon in position with the end even with the carbon clamp and tighten the screw *d* sufficiently to insure good contact; then place the positive carbon with its point ¼ inch away from the negative carbon, and with the end projecting through the clamp, then tighten the screw sufficiently for good contact. Bring the points of the carbons opposite each other by means of the vertical adjusting eccentric *f* and the horizontal adjusting screw *g* and close the obturator shutters.

Each carbon must burn evenly to otain the best results, the negative burning to a point, the positive forming a crater in the center; if they do not they must be adjusted by the adjusting eccentric.

The Search-Light Rheostat.

The single type is shown in Fig. 16. The type is not now used for other than 13-inch and 18-inch projectors, as rheostats for the larger sizes become large and have a dimension from front to back which renders them difficult to install in the locations required for convenient operation; in present practice the

major part of the resistance is installed in one box and without regulating lever—this permits installation at any convenient place along the search-light wiring line—the remaining resistance is enclosed in a small convenient box, having adjusting facilities, at the location of operation (usually near the switchboard).

The rheostat (or rheostats) are installed in series with the line and their office is to cut down the voltage, "have a drop," equal to the difference between the voltage at the switchboard and the operating voltage of the arc; this drop is equal to the resistance of the rheostat multiplied by the passing current. The energy is dissipated in heat and amounts, for a 30-inch search-light, to 5.7 kilowatts for each search-light, or for four, nearly 23 kilowatts, which approximates the total output of a 24 k. w. generator. The loss is severe and has occasioned the consideration of the introduction of a motor-generator for economy; but the intermittent and but occasional use of search-lights hardly warrants the extra device. The rheostats are classed by resistance, current capacity, voltage of the lamp, and line voltage respectively, as in the following example of a 24-inch projector; .62 (ohms), 50 (amperes), 50 (volts, lamp), 80 (volts, line).

FIG. 16.—Search-light rheostat.

The rheostat consists of a dead resistance and an adjustable resistance made up of German silver ribbon, the whole enclosed in a non-combustible frame. The value of the total resistance (hot) allows about four volts below to six volts above the best working voltage of the lamp, the exact voltage required can then be obtained by manipulating the rheostat handle (which controls the adjustable resistance) until a point is reached at which the lamp will work best; as long as the lamp works satisfactorily at this point, the rheostat handle should not be tampered with. The words "*high*" and "*low*" are marked on the rheostat face to indicate in which direction the handle is to be moved to obtain an increase or decrease in the voltage respectively.

The rheostat should be connected in the positive side of the circuit.

Schuckert Company's Projector.—The projector, Fig. 17, in its standard form consists of the following main parts:

FIG. 17.—30-inch projector, Schuckert Company.

1. The foundation, or stand, with the ball-bearings for the turning-tables, the traverse for taking up the sliding rings and the electro-motors with the worm wheel axles.
2. The turning-table with the supports for the pivots of the

drum, the gearings for the vertical and horizontal movement of the drum by hand, and the electro-motors (when electrical control is used), the sliding brushes, chain spanners and the clutches.

3. The drum, containing glass parabolic mirror, lamp with device for moving the lamp, segment for centering the arc of light, "Iris Blind" (darkening apparatus), signalling apparatus, devices for observation and ventilation purposes, and further the necessary parts for the vertical movement of the drum, viz., the pivot, the pivot bearing and the toothed segment.

The stand consists of an upper part, the sheet-iron cone and the foot ring. These three parts surround the traverse which serves to take up the sliding rings and the electro-motors with their gearings. The upper part has a wedge-shaped groove, for taking up the steel ball rim, which serves as a bearer of the turning-table. The surface of the turning-table is level; a little further down, on the outside, is a grooved bracket on which the ball rim lies, and which centers the turning-table. At the inner side of the two ball rims an inner toothing is fixed into which work the raw-hide strips, which rotate the turning-table horizontally. The sheet-iron cone is coupled with the upper part; and the foot ring, and has two large openings for taking out the motors and two small openings for inner inspection. On the foot ring are four eyes with holes for screwing the projector on the stand.

In the center of the traverse a bronze bearing is inserted into which a hollow shaft bears and into the latter a full shaft. Both shafts carry chain wheels on their upper ends, chain and worm wheels on their lower ends; the motor axles work into the latter and are provided with worms. The motors are completely enclosed and have ball bearings which rarely need oiling. They also have ears on both sides and are screwed on bolts which are fastened on the traverse.

The Turning Table.—The cast iron, cap-shaped, turning-table bears the projector drum which is carried on two bronzed arms with cap bearings; the table rotates the drum about a vertical axis. The table rests with its inner side on a steel ball rim which lies in a groove of the stand and is centered towards the latter by a second ball rim placed between the wall of the turning-table and the stand; a center pivot is not necessary. On the turning-table are the enclosed gearings and coupling arrangements

for the horizontal and vertical movement of the drum.. Both gears are so constructed that, by using a coupling nut for each, they permit free movement by hand and hand wheel; this is effected by the following arrangement. The vertical worm shaft works into a loose worm wheel, which is fixed on a hollow shaft, and on which the spur wheel, outside the drum, is keyed to cause the driving of the drum case by a toothed segment. On the hollow shaft is also placed a coupling disc which can be coupled with the worm whéel by turning the coupling nut as far to the left as possible.. On the other side of the coupling disc is a second loose worm wheel, into which the horizontal shaft with hand wheel works; this effects movement by the hand wheel. By turning the coupling nut as far to the right as possible, the disc is coupled with this worm wheel and regulation by the hand wheel can be effected; for the intermediate positions of the coupling nut, none of the worm wheels are coupled, hence a free movement of the drum can be effected by hand.

For turning the projector horizontally within the ball bearings, the stand is provided with an inner toothed device, into which gears a cog wheel which is placed on a vertical shaft, the latter bearing in the turning-table. Above the shaft bearing in the turning-table, a worm wheel is placed on the hollow shaft which can be coupled with the coupling plate on the hollow shaft by screwing down the coupling nut. By turning the worm wheel regulation by the hand wheel in a horizontal direction can be effected. In the intermediate positions of the nut, neither the chain nor the worm wheel is coupled, thus enabling the turning table to be moved by hand.

On the turning-table are sliding brushes which conduct the current for the lamp from the sliding rings which are fixed on the traverse of the stand; movable rollers are also placed on the table which are embedded in movable forks, these are for the chains of the eléctro-motive impetus.

Strong clutches are screwed on the turning-table, at angles of 120 degrees, which work underneath the toothed rim of the stand and thus prevent the table from tipping over when lifting the projector.

The drum consits of a sheet-iron case with a horizontal trunnion, stiffened at both ends by rings, on which on the one end

the glass parabolic mirror with cast-iron frame is placed, and on the other the "Iris Blend" and the front door. The trunnions of the drum and the optical center of the mirror fall together. On the bottom part of the drum is a guide on which the horizontal lamp (hanging on rail brackets) is fixed and through which the detachable carbon holders pass into the axis of the drum. This guide is uncovered by two flaps, leaving a small slot which allows the arms of the carbon holders to pass through and move easily. The lamp itself can be shifted with the carbon holders in the direction of the mirror axis, enabling the placing of the crater of the positive carbons in the focus of the mirror to obtain a concentration of the beam of light.

For the displacement of the lamp a screw spindle is fixed which leads to a worm wheel nut; this nut is turned through the worm by a hand wheel, effecting the movement of the lamp. In order to get at the inner apparatus of the drum and keep it in proper order, several doors are fixed on the drum which work into corresponding grooves of the drum and make a light-tight space.

To prevent the various parts of the drum, and especially the mirror, from getting unduly overheated, ventilation holes are placed on either side of the drum and a chimney on top. These parts are provided with a large number of cross blinds to prevent the escape of light and the penetration of rain and wind.

To suspend the drum, with the pivots in the bearings of the turning-table arms, the two drum rings on either side are connected with two steel rods, on which the pivot bearer is fixed in a movable way, thus facilitating the insertion of the pivots in the horizontal axis of equilibrium of the drum.

On the right-hand side, at the bottom of the drum, is the toothed segment which is used for vertical movement and for which purpose it gears with the corresponding flange rail of the turning-table through a toothed wheel.

The glass mirror, equally thick all over, is cut parabolically on both sides and has an inside diameter of 750 mm. and a focal distance of 310 mm. The mirror is silvered on the back (convex side) and then varnished; the edge of the mirror is embedded with asbestos paper in a cast-iron frame and held in position by a large number of elastic sheet-brass angles. The mirror frame

FIG. 18.—Lamp for 30-inch projector, Schuckert Company.

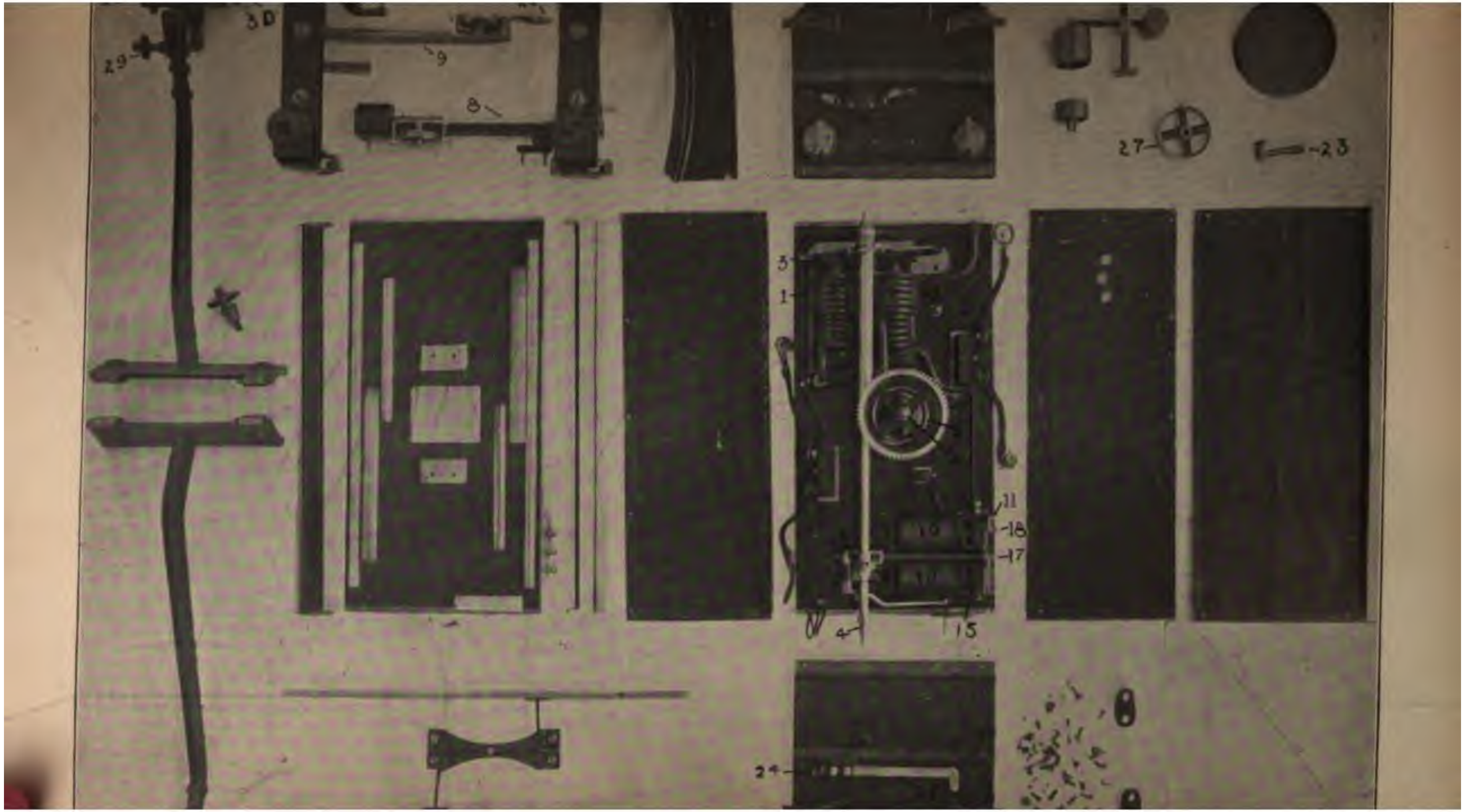
is fastened on by screws and nuts, the former being screwed in the drum ring at the back.

To protect the surface of the mirror at the back, a sheet-iron cover with ventilation holes is fixed on the frame.

Darkening Device.—The "Iris Blind" serves as an effective screen or shutter for the search-light ray. The apparatus consists generally of two concentric rings moving towards each other, one of which is usually tightly fixed on the front edge of the search-light, whilst the other ring can be twisted against the former. To enable an easy rotation of this large ring, it is provided with a groove on its circumference and embedded in a corresponding groove of the solid ring by a steel ball rim. Both rings are connected with one another by thin, sickle-shaped, brass plates, in such a way that the latter are fastened with the pivots on the movable ring whilst the other ends are connected with the fixed ring in the pivots by a short rod. By turning the ring the various sheets are pushed fan-like over one another and thus close the aperture of the projector from the edge towards the center, always leaving an opening of circular shape, which is gradually diminishing; this process much resembles the action of the iris of the eye. A total closing of the center cannot be effected by the sickle-shaped darkening plates themselves unless made extremely sharp; two plate-shaped discs, or blind plates, are therefore fixed in the center in such a way that they form a pulley (with the bottom parts screwed together), with edge-shaped groove, in which the sheets are pressed when closed, thus effecting a light-tight space. These blind plates do not absorb light even if the blind is open, as the center part of the mirror does not send out any useful light on account of the shadow of the negative carbon.

The "Iris Blind" is set in motion by a handle near the edge of the opening of the drum; a slit limits the distance the handle can travel.

Apparatus for Centering the Arc of Light.—To prevent a slant crater a segment of soft iron of about 240 degrees, concentric to the positive carbon, is fixed as near to the light arc as possible; the ends of the segment become magnetic poles to the current passing the carbons, thus creating magnetic lines of force. The latter diffract the arc until the crater is vertical to the axis of the carbon. The segment is supported by two sheet-iron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bearers; it must be removed if the lamp is to be taken out, for which purpose the screw of the horizontal bearer is loosened and the whole put sideways round the lower jointed end of the other bearer.

Horizontal Shunt Lamp.—The lamp, Figs. 18 and 19, is automatic, but can also be regulated by hand, and in both cases be stopped before ignition; on the other hand it can be regulated either way while burning.

The automatic regulation chiefly consists of two magnet systems, one of which produces ("strikes") the arc when switched in, being called the striking arc magnet, whilst the other effects the pushing ("feeding") of the carbons when burning and is called the feed magnet. The arc former consists of a horseshoe-shaped magnet, the arms of which lie in the chief current of the carbons. In front of the pole tips of this electro-magnet, an iron armature 3, Fig. 19, swings on two movable spiral springs which are fastened on the lamp wall. The worm shaft is brought in contact with the iron armature in such a manner that it is forced to travel the same way as the armature.

On the vertical axis 5, is a worm wheel 6, and a toothed wheel 7; the latter gears with the two toothed rods 8 and 9, which are fixed on small movable cars (Fig. 18); the carbon holder arms, jutting on the axis of the mirror, are insulated and placed in sockets of the small cars; the current is led direct to these arms by flexible cables and then to the carbons.

On the lower lamp plate is further placed the feed magnet 10, a horseshoe-shaped electro-magnet. The angle on which the armature bears has on one side an insulated contact screw 11, on the other side the armature 13, with a contact spring; the armature is drawn towards the screw 17 by two screws and movable springs, thus causing the contact spring to come alongside the contact pin 18; the contact spring and pin lie, together with the magnet winding, in the shunt to the carbons. This shunt is interrupted to a certain degree as soon as the armature 13 is attracted by the magnet 10; the shunt is restored as soon as the armature is drawn off by the worm spring. On the armature is a trigger pin 19 which, when attracted, glides over the rack wheel 20 (the latter being fixed on the worm shaft 4), but, when going backwards, it drags the rack wheel along and

thus causes a rotation of the worm shaft 4. This rotation is transferred to the toothed wheel 7 by the worm wheel 6 and thus causes the carbons to approach.

If the carbons do not come in contact with each other when the current is closed the feed magnet begins to act; the automatic opening and closing of the circuit causes the armature to swing rapidly, thus turning the back wheel 20, worm shaft 4, and toothed wheel 7, bringing the carbons together. As soon as the carbons touch each other, the current in the feed magnet 10 is no longer interrupted, the striking arc magnet 1 and 2, however, is strongly excited; consequently its armature is attracted and pushes the worm shaft, with worm wheel and toothed wheel, forward, the carbons are separated from each other, and form the arc of light.

As the burning of the carbons continues, the feed magnet becomes so powerful, owing to the increasing voltage, that it attracts its armature and overpowers the worm springs, until the automatic breaker interrupts the circuit, the armature drops back, sets the rack wheel 20, and also the worm and toothed wheel in motion by the trigger pin 19, and the carbons approach each other. The approaching movement is very small in consequence of the worm transmission and takes place at small intervals, occasioning steady feeding. If the carbons have burned to a certain length, that is, if the toothed rods have arrived at their end position, the current of the feed magnet 10 is interrupted by lifting the spring 22 by a pin 21 on the positive toothed rod 9; the magnet 10 then ceases to work and the arc of light extinguishes slowly.

Hand Feed.—The automatic regulation of the lamp can be switched off and the feeding of the carbons be effected by hand; for this purpose the lever 23 on the rear of the lamp is set from *A* (automatic) to *H* (hand) thus interrupting the circuit of the feed magnet; the contact block 24 which forms the connection, is drawn away from the two springs. The pin 19 is then taken off by the ratched wheel 20, as the pin would hinder the free backward movement of the wheel 20. To bring the carbons nearer the focus, the small wheel 27 must occasionally be turned in the opposite direction to the hand of a watch. If the hand regulation is to be employed from the start, the carbons must first be made to touch each other by turning the small hand

wheeel 27, the carbons must then be quickly separated so that the arc light can attain its proper length.

A rheostat is supplied with the Schuckert projector, which is essentially the same as that used with the General Electric Company's projector.

Focussing.—On both sides of the drum are inserted round, dark, framed glasses which permit observation of the arc of light from the side. In order to control the position of the carbons from above, a little apparatus is fixed in the case, consisting of a mirror and a lens, which reflects an image of the arc of light upon a frosted glass inserted on the top of the case. The larger search-light projectors are also provided with a similar projection apparatus for the observation of the arc of light from the side, reflecting an image on the same frosted glass so that the images are placed underneath each other and by this means the proper insertion of the carbons is effected, as the axes fall together. In the center of the frosted glass is a vertical mark by which the positive carbon can be set in the focus of the mirror in the following way. The ray of the search-light is directed towards the sky at an angle of 20 to 30 degrees and the focus changed by shifting the lamp until the observer, who stands near the search-light projector, finds the beam sufficiently conically pointed (this is caused by the perspective, as the ray is slightly conically extended and drawing to a point should be continued until the ray appears to be shut in behind the point); the beam will then be that for the most favorable position of the crater towards the mirror and it is only necessary to bring the image to the mark of the frosted glass in such a manner that the crater edge and mark are in coincidence to obtain and retrace the right position of the crater by the mark.

Remarks on Care and Cleaning.—The lateral sheet-iron plate of the lamp case can be taken off, permitting access to the interior and an inspection of the gearing, flange rails, pulleys and toothed rods, also for a thorough cleaning with brush and rag.

For lubricating purposes, only the finest watch oil should be used and care must be taken, that it is entirely free from dust.

In handling the inner mechanism, the movable cables must not be damaged or displaced; the edged nuts of the cables must be well screwed on, but the ears on which the cables are suspended should permit of easy movement. Contact and worm

springs on the armatures must not be bent. All contact parts must be kept metallically clean, and care must be taken that the nuts and screws are well screwed on.

If the apparatus is in constant use, it must be cleaned at least once a week. Ashes and particles of carbons which collect on the surface of the lamp, *are not to be blown off*, but are to be carefully brushed off towards the front or back.

Should the feed magnet already operate at a lower voltage than 51.5 volts, the springs have become too weak; this can be remedied by extending the screws until a voltage of 51.5 volts effects the regulation.

Before the lamp is set to work, care must be taken that the carbons are of sufficient length; if new carbons are to be inserted, the carbon holders are extended to their fullest length by the small hand wheel 27; the screws 30 and 31 are raised, the carbons inserted and the screws slightly tightened up again. The positive carbon is then adjusted by the two discs 28 and 29, the former of which serves for the horizontal, the latter for the vertical movements; the position of the carbons is correct when their axes are in the same line. The screws 30 and 31 on the carbon holders should be oiled from time to time. If old carbons are used, it will be advisable to file the two carbon ends into the shape which they tend to assume through burning; the carbons must not touch each other before they are switched in and care must be taken that a good crater is formed from the start. Should the arc of light become one-sided, it can be remedied by so adjusting the positive carbon by the discs 28 and 29 that the less used part of the crater of the positive carbon approaches the point of the negative carbon. For automatic regulation, it should be noted that the stop lever at the back of the lamp is set at *A*. The voltage at which the regulation of the lamp is effected is 51.5 volts; immediately after the lamp is switched in, it works at a lower voltage; when the carbons and wire windings have attained a proper rise of temperature, the feeding will be effected at the normal voltage of 51.5 volts.

General Notes on Projectors.—Dispersing, or diverging, lenses are no longer used.

The principle of operation of the search-light is as follows: With a current of sufficient strength passing through the lamp carbon electrodes, which are first placed in contact and then

separated to about ⅛ inch, a brilliant arc is formed which consists mainly of volatilized carbon particles. The electrodes are consumed, first, by actual combination with the oxygen of the air; and second, by volatilization under the combined influence of the electric current and the intense heat. As a result of the formation of the arc, a crater is formed at the end of the positive carbon. The crater is due to the greater volatilization of the electrode at this point than elsewhere. It is the seat of highest temperature of the arc and is the main source of the light afforded. The major portion of the brilliant light emitted by the carbons is reflected by the mirror and passes out through the plain glass door (in the front of the projector) in a parallel beam.

The beam can be thrown horizontally in any direction, and vertically at any angle (within certain limits) by manipulating the hand control. Regarding the vertical movement of the projector: it is dangerous to keep the beam of light higher than 40 degrees above the horizontal for any length of time, as pieces of incandescent or hot carbon may fall on the mirror and cause it to break. It is only in case of absolute necessity that this limit should be reached or exceeded.

The clutch *p* (Fig. 15) of the General Electric lamp, being the only delicate part of the lamp, has been so located as to be easily removed and inspected.

It can happen that the clutch magnet will keep on working and yet not feed the carbons, due to the following causes:

1. *The Feeding Screw Working Too Freely.*—In this case the whole clutch would move backward and forward at each stroke instead of moving one way only. To remedy this tighten slightly the brake *w* at the back of the lamp.

2. *The Stopping of the Clutch.*—In this case the clutch box would remain stationary and the lever work up and down without turning it; this would be due to oil or water inside the clutch. To remedy this the clutch must be opened and cleaned.

In either of the above cases the lamp could be controlled by hand and would appear to be in working order.

3. *The Sticking of the Clutch.*—This is due to dirt inside, in which case the lamp could not be controlled by hand. To remedy this the clutch must be taken off, opened and cleaned. To remove the clutch, unscrew the nut fixing it to the feeding screw and take out the small pin on the end of the connecting

rod; the clutch can then be pulled out. Open the cover by loosening its two screws, wipe all parts with a clean dry rag and put them back in place.

The two adjusting screws in which the clutch lever rests when in place, *must not be moved.*

4. If the carbons are left burning too near each other a mushroom will form at the end of the negative carbon and which will cut out a great deal of light. The mushroom must be broken as soon as it gets small enough at the neck to permit. To break it, move the positive carbon up and down quickly by means of the adjusting eccentric; bring the carbons to the center as soon as it is broken.

The mirror in the projector gets very hot, consequently great care should be taken not to let any cold air inside the projector drum after putting out the lamp, or while the lamp is in operation, as it might cause the breaking of the mirror. Before turning off the switch on the base of the projector, see that all doors are closed.

If the lamp is put out only to change carbons, the change must be made through the side doors, turning the projector so as to have the opening to leeward; the same course must be followed if for any cause the front door is to be removed.

To prevent damage to the obturator, the carbons must be removed from the lamp when placing it in or taking it out of the drum.

Use the wooden-handled socket wrench to tighten the carbon clamps and also to work the carbon adjusting screws, should it become necessary while the lamp is burning.

The person in charge of the projector must never leave it while in operation, he must constantly watch the burning of the carbons and the focussing of the lamp.

The lamp must be kept clean and free from carbon dust, using the dusting brushes provided for that purpose. Do not blow the dust off. Take care no carbon dust gets into the lamp mechanism or clutch, also keep the drum contact slides and contact guides free from dirt and carbon dust.

Clean off the mirror and front door with a dry rag and polish with chamois skin.

The only parts of the lamp mechanism of the General Electric lamp to be oiled are the four bearings of feeding screws and

the pivot of the armature of the clutch magnet. Clock oil is to be used; be careful to wipe off all the surplus oil. Do not oil carrier slides or clutch. Oil the trunnions and the working parts of the base. Do not oil whilst operating.

After every run, the projector should be put in condition for the next run.

If the projector is not to be used again for some time, the canvas cover should be put over it.

Facing the switch on the projector base, the positive pole is to the left and the negative to the right.

There is often some little flaming of the carbons which cannot be controlled by the rheostat; it is unimportant except from the fact that it decreases the intensity of the light; it will usually disappear of itself. It occurs more frequently when the crater is not central in the positive carbon or when the carbons are not in exact line.

Some hissing will occur when starting up, especially with new carbons, and the lamp will not quiet down until a good crater has been formed in the positive carbon. This can be obviated by reaming out the crater in the positive carbon with a penknife before putting it in the clamp.

Flaming and hissing are promoted by inferior carbons and are much increased if the carbons have absorbed oil. Those now provided are of the Schmelzer or Electra manufacture and are very homogeneous; the positive carbon is bored axially and cored with a soft carbon, which materially assists in maintaining a good crater. Negative carbons have been sometimes cored, but this expedient is quite apt to conduce to the formation of mushrooms. In order to obtain the best results the carbons must be hard, homogeneous and of the best quality. Soft carbons fuse and cause mushrooms on the negative carbon which cut out a large portion of the light and prevent the arc from burning steadily.

The momentary current at starting, especially of short circuit if the carbons touch, is ordinarily heavy and quite sufficient to throw the pointer of the ammeter clear across the scale and against the stops; it need occasion no apprehension if it does not continue; if it does, the switch at the switchboard should be quickly opened. This starting current may be as much as 50 per cent above the working current.

Abnormal current shown by the search-light ammeter is often traceable to either a mushroom on the negative carbon or careless handling of the crank wrench. In most cases of fusing of the contact plungers in the pedestal there has been direct evidence of an attempt to regulate the feed by hand when the automatic gear was switched on. If the lamp does not feed it is for the reason that there has been a burn-out or difficulty in the automatic feed, or that the lamp itself is not clean, and in 90 per cent of the cases dirt is the cause; any attempt to remedy matters by use of a crank wrench, while the current is on, is quite sure to short-circuit the lamp and produce overload.

As a rule it is better to set the carbons before operation and permit no use of the wrench except in focussing. The automatic feed is a very desirable expedient and will give good report of itself if not impeded by an impatient use of the crank wrench. There is rarely any occasion for using the wrench on the screw bar after the lamp is in automatic operation.

The key to good search-light operation and management is thorough cleanliness in all the parts and frequent opportunity for practice by those who are not ordinarily called upon.

The mirrors will spot or frost in time; the action is much hastened on board ship by the practice of exposing them to the rays of the sun while drying out the barrel. There is nothing that will so quickly ruin the silvered surface of a mirror as the action of direct sunlight. Keeping the cover on the projector too much causes sweating, as in the familiar example of the case of guns; it has an important effect in loosening the silvering (frosting).

Inspection of Search-Lights.

Mechanical Construction.—The main points are:

The base is to contain the electrical connections and be so arranged that it can be bolted securely to the deck or platform.

The turntable to revolve freely in a horizontal plane and indefinitely in either direction, or be clamped rigid.

The drum to be trunnioned on two arms bolted to the turntable, giving free movement in the vertical plane; to be designed to be rotated on its trunnions by hand, or clamped rigidly. The vertical movement to cover an arc of 70 degrees above or 30 degrees below the horizontal.

The front of the drum to be provided with a glass door composed of strips of clear plate glass; the door to be readily removable.

The drum to be thoroughly ventilated and fitted with peep sights for observing the arc in two planes, and to have hand holes for access to the interior.

All projectors to be finished in dead black, excepting working parts, which are to be bright.

The Lamp.—*Operation.* The lamp is removed from the drum, and connected up with an electrical source of the same potential as that of the vessel in which the projector is to be used; usually 125 volts is the standard of test.

The rheostat, and an ammeter are connected in the positive leg (unless a shunted ammeter is to be used); a voltmeter is connected across the supply line, and across the carbons at the clamps of the holders.

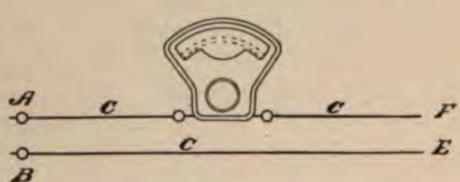


FIG. 20.

The cold resistance of the magnet windings is then taken for calculation of heat rise.

New carbons are put in and the lamp is started in the usual way.

The voltage across the arc just before and just after starting should be noted.

The lamp is then burned for six hours or until the carbons are exhausted.

Note that the arc is well centered and that the motion is steady and even.

Note the voltage and time whenever the feed begins to operate, and voltage when it stops.

Flaming should be slight; note its color.

Note any hissing or sputtering; the best condition is none of either; any sulphurous smell; there should be none; any chipping off of small pieces of carbon; there should be none.

The color of the carbon ash should be grey, not red; the amount of ash should be small.

Note formation of mushrooms on the negative carbon; good negatives should not occasion it; the time of burning out of the carbons, if less than six hours.

At the end of the run the drops on the magnet windings are taken whilst hot, from which the heat rise is calculated.

Insulation Resistance.—The insulation resistances of the lamp are commonly taken when at this stage as being more convenient than when run in the projector.

[NOTE 5.—The method of measuring insulation resistance which is always pursued is by the voltmeter method, which is quite sufficient for any laboratory or ship test.

Referring to Fig. 20, *A* and *B* are the positive and negative terminals of any supply line from the switchboard, and *C, C, C* are leading wires.

First: If the ends of the leading wires, *E* and *F*, are touched together, there will be a deflection in the voltmeter, which is the voltage of the supply line (neglecting resistance of leads).

Second: If *E* (or *F*) is touched to the conductor and *F* (or *E*) is connected to ground or to the adjacent metal from which the conductor should be insulated, there will be a smaller deflection by reason of the extra resistance of insulation between the conductor and the ground or the adjacent metal.

Neglecting minor resistances, the current passing in ***first*** above would be:

$$C = \frac{V}{R} \tag{1}$$

in which V is the voltage of the supply line and R is the resistance of the voltmeter.

In ***second*** the current would be

$$C_1 = \frac{V}{R + R_1} \tag{2}$$

in which C_1 is the current due to V and $R + R_1$; R_1 being the resistance of the insulation.

Since the deflections for the small arc of the voltmeter may be considered as proportional to the currents, we may substitute D and *d* for C and C_1.

Substituting, dividing, and clearing for R_1:

$$R_1 = \left(\frac{D-d}{d}\right) \tag{3}$$

The insulation resistance (hot) which is usually expected is one megohm.

While voltages on board ship are those commonly used for ships' tests, inspection voltages should be 500 volts, as it has been determined by experiment that the resulting insulation resistances increase rapidly as the

voltage falls below 500 volts, and are unduly high at low voltages, while for 500 volts and above the results are fairly constant.

The resistances of voltmeters are always marked on the instrument or on the case.

Often, as in testing, it is only desirable to know that the insulation re-

FIG. 21.—Grating test for mirrors.

sistance is at least one megohm; formula three above is then used in the more convenient form

$$R_1 = R\left(\frac{D}{d} - 1\right)$$

from which, knowing R_1 and D approximately, can be calculated the value of d for $R_1 = 1{,}000{,}000$ ohms: evidently this will be the highest value which d can have, and hence if the voltmeter under *second* above shows a deflection greater than this value of d, R_1 will be less than one megohm: that is, the insulation resistance is not satisfactory.]

The measurements of insulation resistance to be taken for the lamp are: each magnet winding to lamp frame; positive contact spring to lamp frame; negative contact spring to lamp frame; lamp frame to ground (in the projector).

Carbons.—The test of the lamp covers most points in testing the characteristics of the carbons.

They should be hard and homogeneous; without cracks; be round; be straight within 1/16 inch for the entire length; and give a clear, metallic sound when struck.

It is usual to determine the hissing curve, for a particular type of delivery, as proposed by Ayrton; the curves afford a ready graphic means of comparing carbons of different lots or makes.

Mirror.—*Cover and Frame.*—The mirror cover on the drum should be lined with asbestos to protect the operator from the heat; and, while being readily removable, should be capable of firm and secure assembly.

The mirror frame should have a large number of springs which will hold the mirror securely and centrally in place and afford good cushioning, against concussion and shock.

Glass, Silvering, and Backing.—The glass should be clear and free from blow holes and "stars."

The silvering should be even, smooth and free from blotches or frosting; these latter are readily detected by slanting the mirror in different positions.

The backing should be a hard, durable paint, unaffected by heat. It should assure perfect opacity when looking through; this is tested by holding the mirror against the rays of a strong light, an arc light is customarily used.

Curvature.—In this test the focal length is first measured. The mirror is exposed in a frame to the direct rays of the sun when the point of convergence will be immediately recognized and the distance to the mirror can be measured; if there is doubt, the point of convergence can be searched by a piece of paper, which will take fire at the focus.

The mirror is mounted in a frame (Fig. 21), accurately plumbed and accurately centered in front of the square hole of a partition on which is painted a large square, ruled off into smaller squares of about two-inch sides. A camera is inserted in the square hole of the partition and the ruled square illuminated by an arc light.

Fig. 22 shows the photographed results for a rejected mirror in which the lines clearly show poor workmanship in grinding toward the outer edges; for a good mirror the lines are quite straight and equi-distant.

Intensity.—The projector is mounted on a platform and directed at a 10 by 20 foot white target placed 4000 yards for 18-inch mirrors, 5000 yards for 24-inch, and 6000 yards for 30-inch.

The very best conditions of a clear, dark night must be chosen

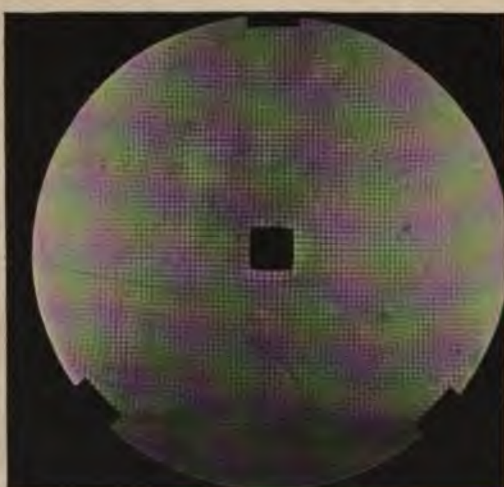


FIG. 22.—Inferior grinding shown by test.

for the test; mist and fog interfere importantly with the penetration of the beam; in the latter case—fog—the beam will not penetrate farther than one or two hundred yards.

Under best conditions the target should show clearly and distinctly.

A further test of carbons, and operation of the lamp when in the projector, is made, after which the following insulation resistances are taken: plungers of base to base; positive and negative leads to base; drum contact springs to drum.

CHAPTER III.

STANDARD WIRE.

Wire for naval use is divided into three general classes:

I. Lighting Wire.—The wire for circuits leading to connections or outlets for which the electrical potential generated by the dynamo is to be used for lighting, or for the operation of motors or other apparatus.

II. Bell Wire.—A type for interior communication circuits which are to be operated by the lower voltage of primary batteries or dynamotors.

III. Cable.—In which single insulated wires are jacketed together or bound together into a circular cross-section for convenience in handling and running; the type affords a reduced cross-section by the elimination of the braid on the separate wires, insures water-tightness particularly when many interior communication lines run through decks and bulkheads, and materially assists in localizing connections.

Construction of Wire.

The general features of the construction of standard wire are illustrated in Fig. 23 and consist of:

1. A *copper conductor, A,* to give the required carrying capacity for the current which is to flow through it.

The smallest cross-section which will contain a given area is the circular, and wires are as a rule made cylindrical. To obtain circularity of section and at the same time gain flexibility the copper conductor is made up of a number of evenly tinned, single wires of 98 per cent conductivity (compared with pure copper), stranded in the so-called "geometric series" consisting of 1, 7, 19, 37, 61, 91, or 127 $[1 + 6 \times 1 + 6 \times 2 + 6 \times 3 + 6 \times 4 + 6 \times 5 + 6 \times 6$, etc., having a summation, $S = 1 + 3n\ (n - 1)]$ single wires in two, three, four, or more layers. The circular construction is farther assured by winding each layer in the opposite direction to that of the last.

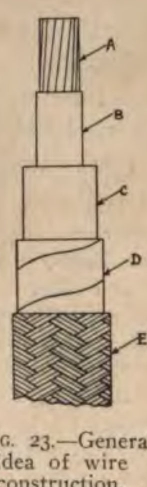


FIG. 23.—General idea of wire construction.

To insure maximum flexibility the pitch of the "standing" or "spiral" lay of all conductors so formed are not to exceed the following tabulated values:

Number of wires forming strand.	Length of pitch expressed in diameters of individual wires.
7	30
19	60
37	90
61	120
91	150
127	180

All single wires forming a strand are of the *diameters* standardized as the "Brown and Sharpe Gauge" as adopted by the American Institute of Electrical Engineers, October, 1893; they are *designated* by the cross-section in circular mils, a notation in which the circular mil is the area of a circle whose diameter is one-thousandth of an inch. The circular mil notation gives a much simpler means of calculation than that involved in the usual method for the area of a circle; in the strand the total number of circular mils is the number of circular mils of the unit, single wire, multiplied by the number of single wires used for that strand.

Due to the twist in stranding, a longer length of single wire being necessary to form the finished strand, the conductivity of a strand is required to be only 95 per cent of that of pure copper instead of the 98 per cent required in the unit wires. It is practicable to obtain unit copper wires of 99 per cent conductivity.

2. *Insulation of the copper conductor, B* and *C,* is to prevent electrical leakage to surrounding material, in other words a protection against grounds, leaks, and short-circuits.

[NOTE 6.—A ground is an undesired connection from an electric conductor or contact to adjacent metal, etc. Its resistance may vary between wide limits, being practically nothing when metallic contact occurs. Its general effect is uneconomical waste of energy.

A ground upon one side of a system only will not affect its operation; that is, if a negative (or positive) wire be connected to the metal, to earth, no leak will occur; no current will flow, provided the positive (or negative) wire of that circuit is properly insulated: but if this positive (or negative) wire be imperfectly insulated, "have a ground" also, leakage and consequent loss of energy will ensue. A partial ground on both sides produces a *leak,* and a dead ground on both sides, a *short-circuit.*]

The wire insulation consists of two elements:

The *first element, B,* is a layer of *pure Para* rubber, which is taped or rolled on to a thickness of about 1/64 inch and is adherent to the copper conductor; it is the ultimate reliance for insulation when its vulcanized-rubber covering, *C,* cracks or flakes, and it becomes mandatory that this layer be of the finest grade of Para rubber, a variety which is the best of the commercial classification. The layer must be 98 per cent pure Para rubber, concentric, of uniform thickness, elastic, tough, and free from flaws and holes.

The *second element, C,* consists of a layer of vulcanized-rubber composition; the compound consists of the best grade of fine unrecovered Para rubber, mixed with sulphur and dry inorganic mineral matter only and containing from 39 to 44 per cent, by weight of fine Para rubber, and not more than 3 per cent, by weight, of sulphur; not more than two-tenths of one per cent of free sulphur is permissible. The layer must be concentric, continuous, free from flaws and holes, and must have a smooth surface and a circular section.

All vulcanized rubber compositions tend to farther vulvanization at any temperature, more rapidly at higher temperatures, until a hard, brittle composition results, in which condition the layer is easily flaked off or cracked; this points out the necessity of allowing an excess in the carrying capacity of the conductor to prevent undue heating and to the avoidance of overload on the circuit wires by installing lights or apparatus whose amperage was not allowed for in the original wire size. The magnitude of the effect on the insulation can be exemplified by considering the fact that the heating effect is C^2R, and that, should the load be doubled, the heating effect would be four times as great; as the resistance would be greater due to heating, the insulation would be subjected to heating conditions over four times that for which it was calculated the completion of vulcanization would be materially hastened, and the undue heating would assist in producing cracking or breaking of the vulcanized rubber layer aside from mechanical injury in handling. There is another factor in the consideration which is that vulcanized products always contain an appreciable quantity of free sulphur; this free sulphur not only combines with the pure Para rubber layer, including it in the process of vulcanization, but it is also hygroscopic, intro-

ducing moisture into the interstices of cracked insulation to promote the occasion of grounds on the line, particularly when there is water in the molding or conduit. It is this injury to the pure Para layer which forms the basis of the restriction of free sulphur to two-tenths of one per cent; it occasions no especial difficulty to manufacturers.

3. *A cotton tape, D,* 1/32 inch in thickness, soaked with a rubber insulating compound; the tape is usually lapped one-half its width in laying on and is so worked as to insure a smooth surface and circular section of the rubber composition beneath, and must not adhere to the rubber. The especial office of this tape is to prevent any deformation of the smoothness of surface or circularity of section of the rubber composition, *C,* in order to secure a neat working fit in a standard rubber gasket, which is to closely fit on the layer, *C,* or over the outer braid and assure water-tightness of the joint; measured dimensions "over vulcanized rubber" or "over tape" must come within 2½ per cent of tabulated values, the departure in no case to exceed 1/32 inch.

4. *A braid, E,* is principally to protect the construction beneath it from mechanical chafe and injury. Its size of thread and the number of threads (usually spoken of as "ends") are determined by the diameter to be covered. All braid must be clearly woven and, silk braid excepted, must be thoroughly saturated with a black, insulating waterproof compound, which compound will neither be injuriously affected nor have an injurious effect on the braid at a temperature of 95° C. (dry heat), or at any stage of the baking test, nor render the construction less flexible. Measurements "over braid" are required to come within 5 per cent of the tabulated values, the departure in no case to exceed 1/32 inch. There may be two exterior braids, but wherever a diameter "over outside braid" is tabulated or specified the outside surface must be sufficiently smooth to secure a neat working fit in a standard rubber gasket of that diameter (over outside braid) for the purpose of securing a watertight joint.

Lighting Wire.

Lighting wire is classed as: Single Conductor, Twin Conductor, and Double Conductor. When greater conducting area than that of 14 B. & S. G. is required, the conductor is stranded

in a series of 7, 19, 37, 61, 91, 127 wires, the strand consisting of one central wire, the remainder laid around it concentrically, each layer is twisted in the opposite direction from the preceding.

Single Conductor.

TABLE OF STANDARD DIMENSIONS.

Approximate C. M.	Actual C. M.	Number of wires in strand.	Size of B. & S. G.	Diameter, inches. Over copper.	Over Para rubber	Diameter in 32ds of an inch. Over vulcanized rubber.	Over tape.	Over braid.
4,000	4,107	1	14	.06408	.0953	7	9	11
9,000	9,016	7	19	.10767	.1389	10	12	14
11,000	11,368	7	18	.12090	.1522	10	12	14
15,000	14,336	7	17	.13578	.1670	10	12	14
18,000	18,081	7	16	.15225	.1837	11	13	15
20,000	22,799	7	15	.17121	.2025	12	14	16
30,000	30,856	19	18	.20150	.2328	12	14	16
40,000	38,912	19	17	.22630	.2576	13	15	17
50,000	49,077	19	16	.25410	.2854	14	16	18
60,000	60,088	37	18	.28210	.3134	15	17	19
75,000	75,776	37	17	.31682	.3481	16	18	20
100,000	99,064	61	18	.36270	.3940	18	20	22
125,000	124,928	61	17	.40734	.4386	19	21	23
150,000	157,563	61	16	.45738	.4885	20	22	24
200,000	198,677	61	15	.51363	.5449	22	24	26
250,000	250,527	61	14	.57672	.6080	24	26	28
300,000	296,387	91	15	.62777	.6590	26	28	30
375,000	373,737	91	14	.70488	.7361	29	31	33
400,000	413,639	127	15	.74191	.7732	30	32	34
500,000	521,589	127	14	.83304	.8643	34	36	38
650,000	657,606	127	13	.93548	.9667	38	40	42
800,000	829,310	127	12	1.05053	1.0818	42	44	46
1,000,000	1,045,718	127	11	1.17962	1.2109	46	48	50

WIRES USED IN STRANDS.

Actual C. M.	Size of wire B. & S. G.	Diameter, inches, over copper.
1,288	19	.03589
1,624	18	.04030
2,048	17	.04526
2,583	16	.05082
3,257	15	.05707
4,107	14	.06408
5,178	13	.07196
6,530	12	.08081
8,234	11	.09074

All single-lighting conductors are insulated as follows (Fig. 24):

A layer of pure Para rubber, *B*, not less than 1/64 inch in thickness, rolled on. On the larger conductors this thickness must be increased, if necessary, to meet the requirements of the bending test.

A layer of vulcanized rubber, *C*.

A layer of cotton tape, *D*.

A close braid, *E*, to be made of No. 20 two-ply cotton thread, braided with three ends for all conductors under 60,000 circular mils, and of No. 16 three-ply cotton thread, braided with four ends, for all conductors of and above 60,000 circular mils.

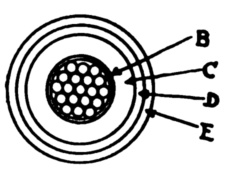


FIG. 24.

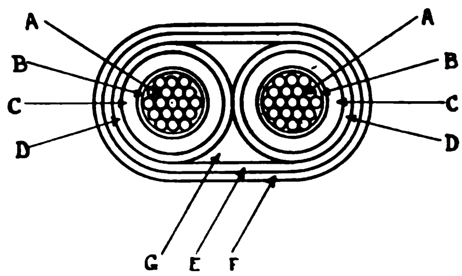


FIG. 25.

FIG. 24.—Cross-section of lighting conductor.
FIG. 25.—Cross-section of twin conductor.

Twin Conductor.

TABLE OF STANDARD DIMENSIONS.

Approximate C. m.	Actual C. M.	Number of wires in strand.	Size of wire B. & S. G.	Diameter, inches. Over Copper.	Diameter, inches. Over Para rubber	Diameter in 32ds of an inch. Over vulcanized rubber.	Over tape. One conductor.	Over tape. Two conductors.	Over 1st braid. One conductor.	Over 1st braid. Two conductors.	Over 2d braid. One conductor.	Over 2d braid. Two conductors.
4,000	4,107	1	14	.06408	.092	5	6	2	8	14	10	15
9,000	9,016	7	19	.10767	.139	7	9	18		20	13	21
11,000	11,368	7	18	.12090	.156	8	10	20	2	22	14	23
15,000	14,336	7	17	.13578	.172	8	10	20	2	22	14	23
18,000	18,081	7	16	.15225	.190	9	11	22	13	24	15	25
20,000	22,799	7	15	.17121	.209	10	12	24	14	26	16	27
30,000	30,856	19	18	.20150	.243	11	13	26	15	28	17	29
40,000	38,912	19	17	.22680	.268	12	14	28	16	30	18	31
50,000	49,077	19	16	.25410	.298	13	15	30	7	32	19	33
60,000	60,088	37	18	.28210	.327	14	16	32	8	34	20	35

All twin-lighting conductors consists of two conductors, each one of which is insulated as follows (Fig. 25):

A layer of pure Para rubber, *B*, not less than 1/64 inch in thickness, rolled on.

A layer of vulcanized rubber, *C*.

A layer of cotton tape, *D*.

Two such insulated conductors are laid together, the interstices being filled with jute, *G*, and covered with two layers of close braid, *E* and *F*.

Each braid is made of No. 20 two-ply cotton thread, braided with three ends.

Double Conductor.—Double conductor is classed as: Double Conductor, Plain; Double Conductor, Silk; Double Conductor, Diving Lamp.

Double Conductor, Plain.—The center conductor is constructed as follows:

A copper conductor, *A* (Fig. 26), consisting of seven No. 22 B. & S. G. wires, six of the wires to lay around the seventh.

A layer of vulcanized rubber, *B*, to an external diameter of 0.181 of an inch.

FIG. 26.—Cross-section of double conductor, plain.

A close braid, *C*, of No. 60 two-ply cotton thread, braided with three ends.

The above form the core and the wires of the second conductor, *D* (seven No. 22 B. & S. G.), are laid around it over the braid concentrically and smoothly, the pitch of the lay is about 1½ inches.

Over both conductors is:

A close braid, *E*, of No. 60 two-ply cotton thread, braided with three ends.

A layer of vulcanized rubber, *F*, to an external diameter of 13/32 inch, to be vulcanized before braiding.

A layer of cotton tape, *G*, about 1/32 inch in thickness.

A close braid of No. 30 three-ply linen gilling thread braided with two ends, *H*.

A close braid, *I*, of No. 30 three-ply linen gilling thread braided with three ends.

The finished dimension is 19/32 inch.

Double Conductor, Silk.—Each conductor is constructed as follows:

A stranded copper conductor, *A* (Fig. 27), consisting of seven No. 25 B. & S. G. untinned wires, six wires to lay concentrically around the seventh.

A close braid or wrapping, *B*, No. 80 Sea Island cotton thread.

A layer of vulcanized rubber, *C*, to a diameter of 4/32 inch.

A close braid, *D*, of No. 60 two-ply cotton thread.

A close braid, *E*, made of hard-twisted olive-green silk.

Two conductors thus constructed are *twisted together* to form the finished conductor.

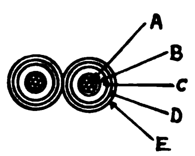


FIG. 27.

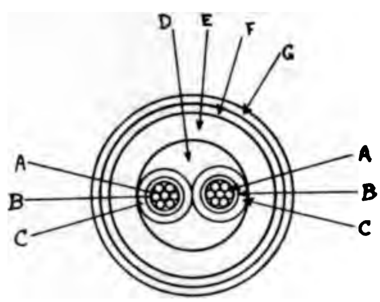


FIG. 28.

FIG. 27.—Cross-section of double conductor, silk.
FIG. 28.—Cross-section of double conductor, diving lamp.

Double Conductor, Diving Lamp.—Each conductor is constructed as follows:

A conductor, *A* (Fig. 28), consisting of seven No. 20 B. & S. G. wires, six of the wires to lay around the seventh.

A layer of pure Para rubber, *B*, rolled on, of a thickness not less than 1/64 inch.

A layer of vulcanized rubber, *C*, to an external diameter of 0.186 inch.

Two conductors thus constructed are laid up or twisted together, and filled with jute lateral, *D*, to a circular section and an external diameter of 0.372 inch. The jute is saturated with an insulating compound.

Then to be covered with:

A layer of vulcanized rubber, *E*, to diameter of 18/32 inch.

A close braid, *F*, of No. 30 three-ply linen gilling thread, braided with three ends.

A close braid, *G*, of No. 30 three-ply linen gilling thread, braided with four ends.

The finished dimensions is 22/32 inch.

Bell Wire.

Bell wire is classed as bell wire and bell cord.

Bell Wire.—Bell wire is constructed as follows:

A conductor consisting of one No. 16 B. & S. G. wire.

A layer of vulcanized rubber to a diameter of 0.113 inch.

A close braid of No. 40 two-ply cotton thread, braided with three ends to a diameter of 0.14 inch.

Bell cord, double, triple, and quadruple, consists of a twist of two, three, or four of the single wires specified for Double Conductor, Silk, and is used for wiring single, double, and triple pear push buttons. When bell cord, double, is required double conductor silk is usually used.

Cable.

Cable is classed as follows: Interior Communication Cable; Cable for Night-signalling Sets.

Interior Communication Cable.—Each unit conductor (Fig. 29) consists of seven No. 24 B. & S. G. wires, *G*, the seven grouped to approach circularity of section; the whole is wrapped with No. 80 cotton thread, *H*, to a diameter of 0.068 inch, then covered with vulcanized rubber compound, *F*, to a diameter of 0.136 inch, then braided with No. 60 white cotton thread, *E*, braided with three ends, the over-all diameter to be 0.156 inch.

FIG. 29.—Cross-section interior communication cable.

The requisite number of unit conductors, ten in the figure, to be laid up with a twist (having been filled with jute laterals, *A*, to approach circularity of section), then covered with:

A layer of cotton tape, *B*.

A layer of vulcanized rubber, *C*.

A close braid of No. 20 two-ply cotton thread, *D*, braided with three ends, for all cables of less than twelve conductors, and of

No. 16 three-ply cotton thread, braided with four ends, for all cables of above twelve conductors.

One unit conductor in each cable of and under seven wires, and one wire in the inner and one wire in the outer layer in each cable in excess of seven wires has three adjacent black threads woven in the white braid.

DIMENSIONS OF STANDARD INTERIOR-COMMUNICATION CABLE.

	Number of wires.				Diameter in inches.		Diameter in 32ds of an inch.	
Conductors.	1st layer of core.	2d layer.	3d layer.	4th layer.	Over conductor.	Over tape.	Over vulcanized rubber.	Over braid.
3	3	..	..	..	..	.3987	17	19
4	4	..	..	..	..	.4395	18	20
5	5	..	..	..	..	.4841	20	22
6	6	..	..	..	..	.5312	21	23
7	1	6	..	..	..	.5312	21	23
8	1	7	..	..	..	.5785	22	24
9	1	8	..	..	..	.6350	25	27
10	1	9	..	..	..	.6750	26	28
11	2	9	..	..	..	.6875	26	28
12	3	9	..	..	..	.7112	27	29
13	3	10	..	..	..	.7235	28	30
14	4	10	..	..	..	.7520	29	31
15	4	11	..	..	..	.7729	30	32
16	5	11	..	..	..	.7966	31	33
17	5	12	..	..	..	.8220	31	33
18	6	12	..	..	..	.8430	32	34
19	1	6	12	..	..	.8430	32	34
20	1	6	13	..	..	.8800	33	35
21	1	7	13	..	..	.8910	33	35
22	1	8	13	..	..	.9325	35	37
24	1	8	15	..	..	.9875	37	39
26	2	9	15	..	..	1.0000	38	40
28	3	10	15	..	..	1.0360	39	41
30	4	10	16	..	..	1.0645	40	42
32	4	11	17	..	..	1.0854	41	43
34	4	12	18	..	..	1.1345	42	44
36	6	12	18	..	..	1.1562	43	45
38	1	6	12	19	..	1.19125	44	46
40	1	7	13	19	..	1.2035	45	47

UNIT CONDUCTORS (STRANDED).

Wire.		C. M.	Diameter in inches.			
B. & S.	Number of strands.		Over copper.	Over cotton wrapping.	Over vulcanized rubber.	Over braid.
24	7	2,828	.060	.068	.136	.156

Cable for Night-Signalling Sets.—Each conductor is made up of nineteen strands (*A*, Fig. 30) of No. 25 B. & S. G. wire.

The insulation is made up as follows:

First. A layer of Para rubber, *B*, 1/64 inch thick rolled on.

Second. A layer of vulcanized rubber, *C*, to a diameter of 0.257 inch.

Third. A layer of 1/32-inch thick cotton tape, *D*, lapped one-half width.

Fourth. A close braid of No. 30 three-ply linen gilling thread, *E*, braided with two ends; the diameter over braid to be 3/8 inch.

Sixteen conductors so constructed are laid up in the finished cable.

The cable is constructed as follows:

The heart of the cable consists of a continuous length of 9-thread, tarred, well-stretched hemp rope, *G*; the upper end of the heart extends beyond the end of the cable conductors and is finished with a neat, strong eye splice 3 inches in length.

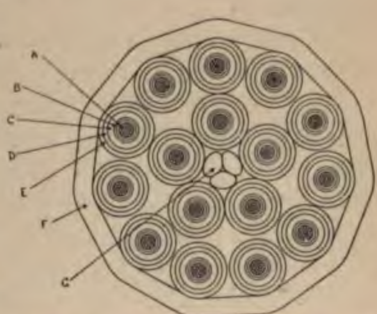


FIG. 30.—Cross-section night-signalling cable.

Around the heart are laid five of the unit conductors; the lay is spiral, with left-hand twist, and of such a pitch as will closely assemble the conductors on the heart.

On the inner lay are laid the remaining eleven unit conductors; the lay is spiral, with right-hand twist, with jute filling, and of such a twist as will closely assemble the conductors on the inner layer.

The conductors are branched out for the lamps in pairs, using adjacent conductors; the reduction caused by branching is made in a neat taper by filling in with dead wire or jute; branching is first done from the outside layer of the cable and is spaced for 12-foot distance between the lantern centers, unless otherwise directed.

The outer layer of conductors is securely hitched with marline hitches, *F*, 1 inch apart, using a six-ply flax twine of about 1/8 inch diameter; the hitching is for the entire cable length.

In order to overcome induction from the aerial of the wireless, the upper end of the cable is closely served with No. 26 B. & S. G. iron wire, for a distance of about 10 feet down, commencing 50 inches below the top of the upper lantern.

The lower, keyboard, end of the cable is fitted with a navy standard male coupling. The cable is furnished in special lengths, as required, the length being measured from the coupling to the first outlet.

Inspection of Wire.

Quantity Delivered.—The length of wire on each reel is checked by running the wire through a registering counter, somewhat on the design of the counter of navigational sounding machines.

The end of the wire is taken between the swallows of two sheaves. The upper sheave is attached permanently to its axle, on which axle is a gearing which actuates a train of wheels moving a pointer over a dial, registering in feet. The lower sheave is larger, is also attached to its axle, but the axle journals in bearings set in a movable guide which has a vertical motion against a spring; this arrangement permits of accommodating the distance between the sheaves to varying diameters of wire; the spring also holds the lower sheave up against the wire, which in turn presses firmly against the upper sheave to avoid lost motion or slipping which would invalidate the dial indication; as the wire is pulled through it is reeled up on a horizontal reel whose posts are removable, leaving the wire coiled in readiness for the tank (for insulation resistance).

Test Samples.—From each reel is cut a 5-foot sample, which is divided up into five test samples as follows:

Sample No. 1, Three Feet Long.—This sample is used for all physical tests, not included under the chemical, baking, and braid tests, and also for the determination of the conductivity of the copper conductor. As the different layers are stripped off, the following are examined into:

That the diameters of each component layer of the construction, as prescribed by the tabulation, is correct, with special reference to that over vulcanized rubber and braid; these diameters are gauged on at least three planes to test the circularity of section. In order to insure watertightness, a rubber composition gasket

is used as a packing which is designed to fit over the vulcanized layer or braid on the wire (jacket of cables); the orifice of the gasket is exactly prescribed for a particular use, and it becomes mandatory that the section be circular and the diameter over the layers which are to fit in these gaskets be exact. The diameter over the outer braid of the finished construction is also important as determining the clearance which will be available when the wire is drawn in conduits; it is economical to draw as long lengths as possible, and undue stress on the wire must be avoided to prevent rupture or stress of the components of the wire construction through stretching; cables require especial care in this respect as regards the unit conductors.

That the waterproof insulating compound has thoroughly soaked the outer braids, determined by examining the inside surface; and that the proper number of threads (ends) are used and are closely woven. The number of ends prescribed are those which assure a neat fit over the underlying construction.

That the tape is thoroughly saturated with the insulating compound, and that it is smoothly lapped one-third to one-half. Tape layers are intended to act as a binding which will assure circularity of section of the vulcanized rubber layer which is to fit the gaskets, and to insure circularity for the braid; it is important that the tape does not adhere too closely to the vulcanized rubber. Tape should be carefully examined for folds or breaks which would produce roughness or imperfection of the vulcanized rubber layer. The insulating compound used on the tape is generally a rubber compound and is tested by burning a weighed sample; the characteristics required are rather waterproofing than insulating, the insulating is prescribed as it accomplishes both.

That the layer of pure Para rubber, next to the copper conductors, is uniform, free from flaws or holes, and, if taped, that the tape laps one-half, making the surface uniform. This determination must be made by examination of the longitudinal section and interior surface as, due to vulcanization from free sulphur, the line of demarcation between the pure Para rubber layer and vulcanized rubber is seldom distinct.

When the copper conductor has been stripped of layers, any adherent rubber is dissolved off with benzine and each wire composing the strand is examined for thoroughness and evenness of tinning, when so specified.

A length of one foot of all rubber layers is carefully removed in stripping for the determination of tensile strength and elongation, a test which is made in connection with the chemical test.

Determination of Conductivity.—The sample of copper conductor is weighed, the weight being taken in grammes. Three of the unit wires composing each strand of the copper conductor are then separately tested for resistance in the X arm of a box of resistance coils arranged as a Wheatstone bridge and connected up with a Queen and Company's modification of the D'Arsonval galvanometer; the battery used is two cells (4½ volts) of an Electric Power and Storage Battery Company's accumulator. From the mean of the three resistances, and the mean of the weights of the three wires, the percentage of conductivity, as compared with that of pure copper at the temperature of 75° F., is determined by the following formula:

$$\text{Conductivity per cent} = \frac{L \times L \times 1.44268}{W \times R \times K}$$

in which L is the length of the original conductor (3 feet); W is the weight of the length of the original copper conductor; R is the mean resistance of the three wires measured; K is the temperature coefficient, generally derived from a predetermined curve, which reduces R for the temperature of 75° F. This convenient formula is derived from the metre-gramme determination of Matthiessen for copper resistance at 0° C., and is calculated for the foot-gramme at 75° F., reduced to percentage of conductivity. Results of 99 or 100 per cent are latterly not infrequent for good wire.

Sample No. 2, Six Inches Long.—This specimen is placed in an oven, which consists of a sheet-iron box covered with a non-conducting layer of asbestos wool; three steam coils inside the box vary the temperature in accordance with changes of steam pressure. A thermometer is inserted through an aperture in the top of the box. The front is provided with a glass door, through which the sample and thermometer can be observed. The temperature is raised to 95° C. At the expiration of four hours the specimen is cooled in the air and then sharply bent to a radius seven times the wire diameter; it should develop no breaks of cracks in either the braid or insulation and the compound should show no tendency to run out. The specimen is subjected to

several similar tests over an interval of three days. For twin conductor the minimum diameter is the basis of bending.

Double Conductor, Silk, and Bell Cord are not baked.

Sample No. 3, Six inches Long.—The test of this sample is for determination of the water-repellent qualities of the outside braid and the tape. The ends of the specimen are dipped into hot paraffin, the specimen is weighed and is then submerged in water for 48 hours. When taken out it is again weighed, after drying the exterior surface, and the results reduced to percentage of absorption for braid and tape by subtracting the weight of the component layers of the wire which they cover. An absorption of 15 per cent is permitted.

Silk-covered conductors are not tested for absorption, as they are not expected to be waterproof.

Sample No. 4, Six Inches Long.—This sample is tagged and retained for future reference, especially with regard to re-inspection when occasioned by rejection.

Sample No. 5, Six Inches Long.—This sample is forwarded to the chemist and is tested: First, by microscope to determine as to cotton, linen, jute, and silk; the fibers are so distinctive for each that compliance with specification is readily tested without recourse to chemical re-agents or stains except as a check in case of doubt.

Second, for determination of rubber constituents. The analysis of rubber compounds consists in determining the following:

Extractive Matter, Saponifiable Matter, Mineral Matter, Vulcanized Rubber, Sulphur and Gum.

The Extractive Matter consists of resins, free sulphur, and sulphinated products.

Saponifiable Matter consists of rubber substitute.

Mineral Matter is the ash.

The Vulcanized Rubber consists of the gum and the sulphur.

The sample to be analyzed is digested with acetone for two hours; it is then dried for about half an hour, cooled and weighed. The loss represents the extractive matter. The solution is evaporated to dryness, taken up in alcohol, and divided into two parts: one part is treated with concentrated nitric acid, allowed to digest on a steam bath, filtered, and the filtrate precipitated with barium chloride and allowed to settle over night; then filtered off and weighed, from which sulphur is calculated. This is the free

sulphur. The other part is evaporated to dryness, taken up in neutral alcohol, titrated with fiftieth normal caustic potash; this, when calculated to abietic acid, represents the resins.

The residue from the previous operation is treated with 8 per cent caustic alcoholic soda and allowed to stand for 8 hours on the water bath. The alcoholic extract is then poured off and washed well with hot water, adding a little hydrochloric acid until neutral, and then dried and weighed. This weight, deducted from the previous weight, represents the amount of substitute present in the sample. This residue is ignited in a porcelain crucible and is calculated as mineral matter.

The sum of the extractive matter, saponifiable matter, and mineral matter, subtracted from 100, denotes the percentage of vulcanized rubber.

The total sulphur is separately determined: about one gramme of the sample is weighed into a 2-inch porcelain capsule and treated with a small amount of fuming nitric acid; when the evolution of gas has ceased the capsule is filled up with fuming nitric acid and allowed to stand over night; in the morning it is evaporated almost to dryness on the water bath. The residue is neutralized with magnesia, stirring with a small platinum rod and ignited, cold water is added and dissolved in hydrochloric acid; it is now filtered and the sulphate precipitated with barium chloride. On standing over night the barium sulphate is filtered off, ignited, weighed, and calculated to sulphur. This represents the total sulphur. This sulphur, subtracted from the amount of vulcanized rubber, gives the percentage of gum. This percentage of gum represents the actual amount of chemically pure gum present; but as the Para gum contains an extractive value of its own, normally 2½ per cent, the 2½ per cent should be added to the amount of gum to determine the actual amount of gum used (to be 39 to 44 per cent fine Para).

In interpreting these results, the amount of extractive matter is the best guide to determine the quality of gum used. The evidences of regenerated rubber and rubber substitute are shown by high extractive values. If free sulphur has been found to be present it must be subtracted from the total sulphur before deducting the sulphur from the vulcanized rubber.

Asphaltum is detected in a rubber composition by treating the residue from the saponification with cold nitro-benzole for one

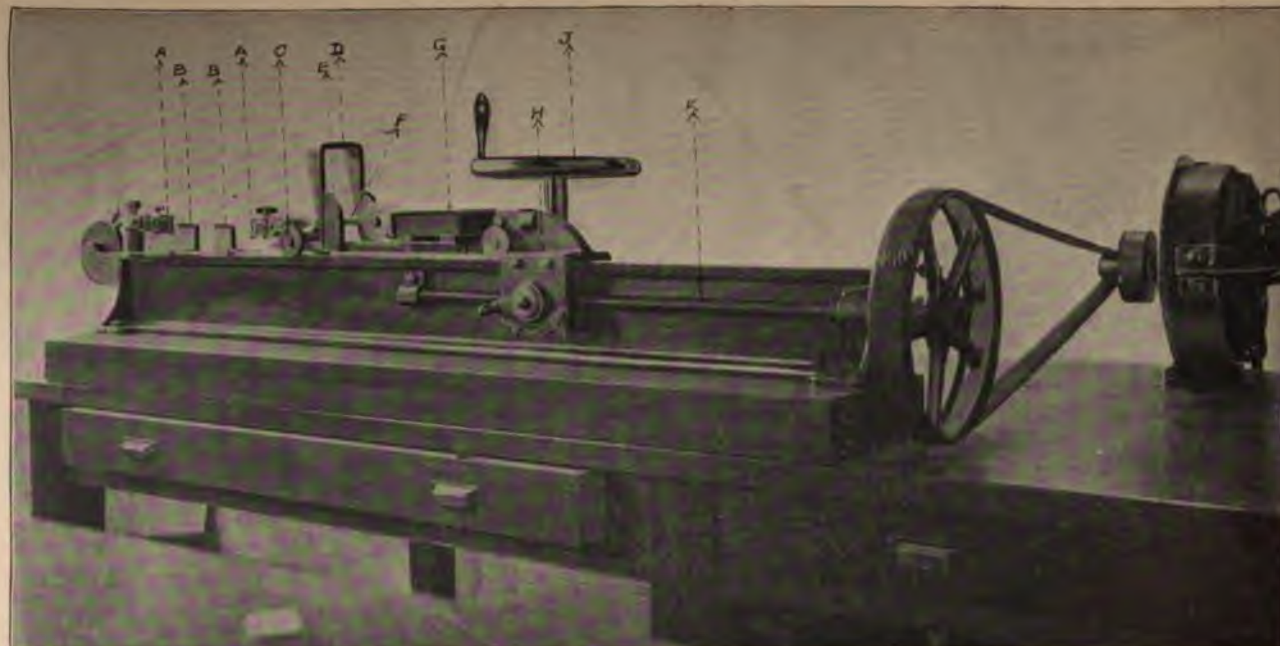


Fig. 31.—Riehlé testing machine.

hour. The nitro-benzole is poured off and the residue washed with ether; this residue is dried and weighed, the loss in weight representing the amount of asphaltum present. If asphaltum is present, the amount of sulphur in the asphaltum must be determined and deducted from the total sulphur, as in the case of the free sulphur. If substitutes are present, the amount of sulphur in the substitutes must also be determined and deducted from the total sulphur.

If an examination of the mineral part of the compound shows compounding with lead, the first precipitate of barium sulphate used in determining the total sulphur must be treated with hot concentrated nitric acid, washed with hot water, and the barium sulphate weighed off; this step is necessary to free the barium sulphate from lead sulphate.

Test of Tensile Strength.—The chemical test will not indicate conclusively the quality of the rubber used as regards age, that is, it will not entirely determine whether old stock, refuse, or reclaimed rubber has not been worked up in the composition, adulterations which would cause insufficient strength against stretching; to determine this the tensile strength and elongation of the vulcanized rubber layer is tested, as an adjunct to the chemical test, by the Riehle testing machine shown in Fig. 31. (A more modern type is now actually used but the details are similar.)

The pieces which were stripped from the conductivity specimens are first carefully separated from their pure Para rubber layer and cut into lengths of 5 inches by ½ inch. Three specimens are selected for the test, their specific gravity determined, and the width and thickness calipered for cross-section. A specimen is then secured in the jaws, *A*, the distances between the markers, *B*, being set for two inches; the fiducial positions of the markers, *B*, are marked in ink on the specimen. A motor belted to the wheel of the screw-shaft, *K*, is set in motion, the screw-bar giving a rate of separation of the jaws of three inches per minute. The screw-bar gears in the block, *H*, which is rigidly connected to the framing of the spring scale, *G*; the scale is similar to the circular-face scale used commercially for weighing, has a capacity of 50 pounds, and its scale registers one-tenth of a pound. The body of the spring scale travels on rollers; the tongue of the scale, *F*, is attached to the nearer jaw, this jaw being secured to a car moving on the roller, *C*. The hand wheel *J*,

is for operating the mechanism by hand but the motor is preferable as the rate of separation of the jaws can be regulated as desired and is more constant.

As the jaws separate, the markers, *B*, are kept to the original fiducial marks; a reading of the elongation in tenths of an inch is taken for every two pounds of tension shown by the spring scale. As the jaw, *A*, moves out on the roller, *C*, a wedge of sheet metal, *D*, drops down between the follower, *E*, and a lug on the car near *C*; this wedge, *D*, prevents a jar to the spring-scale mechanism when the specimen breaks or tears, locks the car for the exact point of elongation, and also locks the pointer of the spring scale for the exact tension. The mean of the elongation and tensile strength of three specimens is taken, the test results of stress being reduced to the basis of the square inch. The prescribed breaking strain per square inch is not less than 1000 pounds per square inch and the elongation is to be at least 3½ times the original length between marks (that is, at least 7 inches). A second similar sample is subjected to a test for permanent set by subjecting it to a stress of 900 pounds per square inch (9/10 of specified breaking stress) for 10 minutes; the vulcanized rubber compound should be of such a character as to return to within 50 per cent of its original length at the end of 10 minutes after release from stretch.

Continuity and Insulation Resistance.

Continuity.—The continuity of *every copper conductor* of each parcel of wire is tested by placing each separate conductor of the reel length in series with an incandescent lamp and a switchboard using the lamp voltage. It is sometimes tested by "ringing through," using the standard magneto.

It occasionally happens that the conductor has been broken in course of manufacture, the case occurs more often with interior-communication cables.

Insulation Resistance.—Each reel of wire is submerged for 24 hours in a large iron tank containing a solution of salt and water, 1½ pounds of salt to the cubic foot of water. Both ends of the wire are left suspended above the surface of the water; the layers at the ends are trimmed back, exposing the copper conductor for about one inch, and the joint and trimmed portion is covered with paraffin. At the end of 24 hours after immersion

the insulation resistance test is made by the direct-deflection method, a galvanometer being used instead of a voltmeter in this test.

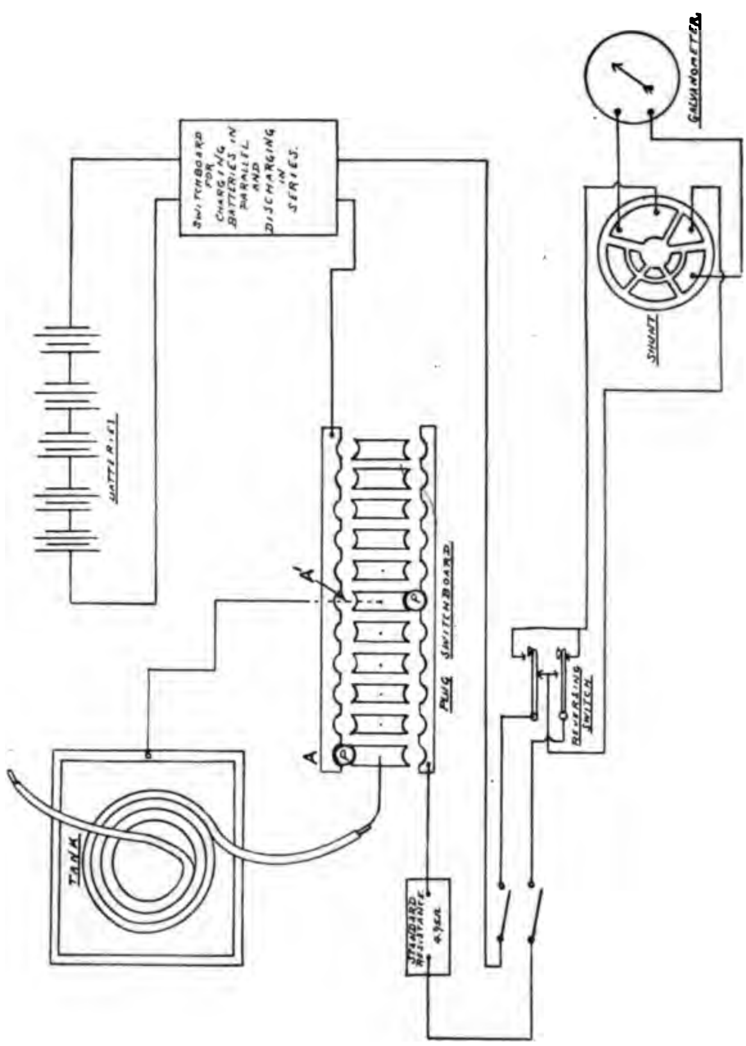


FIG. 32.—Connections test of insulation resistance.

Referring to Fig. 32, 500 volts are tapped off from a storage battery at the charging switchboard through the plug switchboard. The plug switchboard consists of two bus bars and a

series of brass blocks which can be connected to the bus bars through plugs, P; the middle block is connected to the metal of the tank. One end of the wire under test is connected to the block, A, through low-resistance leading wires which are clamped to the end of the copper conductor of the wire by a set screw. The lower bus bar is connected to a standard resistance of 4.95 megohms. The plug at A is first inserted at A' and the main switch (shown underneath the standard resistance) is closed; on closing the reversing switch a deflection is obtained due to the standard resistance alone, since the wire under test is cut out by moving P to A'. From this deflection the galvanometer constant is obtained:

Galv. Const. $= 4.95 \times$ Deflection $\times$ Multiplying power of shunt.

The plug, P, is now moved to A. On closing the main switch and reversing switch the cable is electrified and is allowed to charge for five minutes; the deflection obtained on discharge is due to the insulation resistance of the wire in series with the standard resistance, the resistance of connections being negligible in comparison. The insulation resistance in megohms per knot is then obtained from the formula:

$$\text{Ins. res.} = \frac{\text{Galv. Const.} \times \text{Length of wire in feet}}{\text{Deflection} \times 6086} - (4.95 \text{ megohms}).$$

The standard resistance is kept in series merely for convenience in retaining as permanent connections as possible.

In all finished constructions involving more than one conductor, each conductor is first tested to ground as above. The connection to the tank is then broken and both connections of Fig. 32 are led to adjacent wires of the construction to obtain the insulation resistance *between conductors*, tests being made each to each, and in the same manner as if to ground. Silk-covered wires are not put in the tank; the coils are suspended in the air and only the resistance between conductors is tested.

The prescribed insulation resistance for different types of wire is shown in the following table. (The last column is the voltage for high potential test explained later under Inspection of Generating Sets.)

Lighting wire.	Insulation resistance.	Test voltage, 30 minutes.
Up to and including:		
500,000 cm., single	1,000 megohms per knot	4,500
650,000 cm., single	900 megohms per knot	4,500
800,000 cm., single	800 megohms per knot	4,500
1,000,000 cm., single	750 megohms per knot	4,500
All twin wire:		
Between conductors	1,000 megohms per knot	3,500
From conductors to ground	1,000 megohms per knot	3,500
Double conductor.		
Plain:		
Between conductors	1,000 megohms per 1,000 feet	2,500
Each conductor to ground	1,000 megohms per 1,000 feet	3,500
Diving:		
Between conductors	1,000 megohms per 1,000 feet	3,500
Each conductor to ground	1,000 megohms per 1,000 feet	3,500
Silk	No test	5,000
Bell wire	500 megohms per 1,000 feet	1,500
Bell cord	No test	5,000
Cable.		
Interior-communication cable:		
Between conductors	1,000 megohms per 1,000 feet	1,500
Each conductor to ground	1,000 megohms per 1,000 feet	3,500
Night-signal cable:		
Conductor for	1,000 megohms per 1,000 feet	3,500
Completed cable—		
Between conductors	1,000 megohms per 1,000 feet	3,500
Cable to ground	50 megohms per length	3,500

[NOTE 7.—These minima of insulation resistances are derived from experiments on the different compositions used and, in the case of lighting wire, the empirical formula commonly used for determination in thousands of megohms per knot is that of the rectangular hyperbola:

$$xy = .742$$

x being the insulation resistance required:

y being the diameter of the copper conductor:

0.742 being the diameter of the copper conductor of a 400,000 cm. wire, for which the formula gives 1000.

The theoretical formula,

$$\text{Ins. res. per knot} = \frac{1}{2\pi L} \times \log_e \frac{D}{d},$$

in which D is the diameter over insulation and d the diameter over the copper conductor, is reduced by practical wire makers, after introducing common logarithms and the specific resistance of the rubber compounds

used in standard wire (at 72° F. for two minutes electrification), to the approximate form:

$$\text{Ins. res. per knot} = 10{,}000 \log \frac{D}{d},$$

which agrees very closely in results with that of the hyperbola above given.

These formulæ show the following results:

For	4,000 cm.,	11,594	megohms	per	knot.
"	50,000 "	2,921	"	"	"
"	100,000 "	2,044	"	"	"
"	400,000 "	1,000	"	"	"
"	650,000 "	794	"	"	"
"	800,000 "	706	"	"	"
"	1,000,000 "	620	"	"	"

As insulation resistance varies inversely as the contact surface of the rubber on the copper, wires larger than 400,000 cm. should be expected to maintain a test of about 700 megohms per knot instead of 1000. Formerly it was the custom to electrify a wire for only one minute, but a curve from experiments made at the New York Navy Yard shows that electrification of from 10 to 14 minutes give more characteristic results; the curve drops slowly after 5 minutes, and that interval has now been selected.

The effect of the voltage used for test has been mentioned, 500 volts being a desirable value.]

In the inspection of cables it is important that the wire in each layer which is specified to be covered with a braid containing white threads be so covered; the device is a necessity for connecting, tracing, and testing separate wires after installation.

CHAPTER IV.

WIRING APPLIANCES.

The general term "Wiring Appliances" is extended to include molding, conduit, insulators with their clamps, stuffing tubes, box tubes, terminal tubes, fuses, gaskets, tape, etc.; the strict interpretation is confined to devices intended for wiring connections for the control of current feed, such as junction boxes, switches, and the like.

The general term may be divided into four classes:

I. Ducts (including insulators).
II. The Box Types; usually watertight.
III. Non-watertight Types.
IV. Auxiliary Appliances.

Ducts.

Ducts afford the most convenient method of protecting lines of wiring, and are divided into two general classes in ship-wiring, molding, and conduit. The main distinction is that molding has grooves or channels made in wood, while conduit is some variety of metal or other pipe.

Molding.—Molding is divided into two classes: molding for lighting-wire, and molding for bell-wire and cables; the varieties for each class are designated by the width.

In Fig. 33 *A* is the lighting-wire molding and *B* is the bell-wire molding. *C* is an especial type of molding sometimes used for the dynamo leads; the three-gutter portion is for the positive, negative, and equalizer connecting wires which lead to the switchboard, the two-gutter portion is for the shunt-connecting wires leading to the rheostat.

Molding consists of three parts: that part containing the gutters for the wires, *D*, is called *molding;* that part upon which the molding rests, *E*, is known as the *backing strip;* and that part which covers the gutters, *F*, is the *capping*. The *backing strip* is usually ¾ inch thick; the width depends upon the number of lines of molding which are to be run over it; that is, if several lines of molding are to be run, side by side, the backing strip for those lines would be a board, ¾ inch thick, and of a width equal to the sum of the widths of the several moldings. When

bolt or rivet heads, etc., jut out more than ¾ inch, the thickness of the backing strip must be increased. Backing strip is not used if the molding is to be run over a smooth or wooden surface. All *capping* is of the same width as the molding, and is ⅜ inch thick; to prevent warping it must be screwed to the side walls of the molding and not to the center wall.

Both molding and backing strip are made of thoroughly seasoned white pine; they are coated with white-lead paint after being fitted and before securing in place. When run over hard-wood

FIG. 33.—Types of ducts.

surfaces all parts are of the same material and finish as the surrounding wood work.

The following are the standard dimensions of lighting-wire molding; bottoms of gutters to be semicircular in section:

For all feeders and wires of 60088 c. m. to 124928 c. m., inclusive—3 inches wide, 1½ inch deep, including capping; to have two gutters each ¾ inch wide and ¾ inch deep, gutter separated by a ¾-inch wall; outside walls to be ⅜ inch.

For wires below 60088 c. m.—¾ inch wide, 1⅜ inches deep, including capping; to have two gutters, each ⅝ inch wide and ⅝ inch deep, gutters separated by a ¾-inch wall; outside walls to be ⅜ inch thick.

The following table shows the standard dimensions of molding

for bell wire; bottoms of gutters to be semicircular in cross-section:

Type.	Width. Inch.	Depth. Inc. Capping. Inch.	Cutter Inch.	Side Walls. Inch.
2¼-inch	2¼	1¾	1	⅝
2½-inch	2½	2	1¼	⅝
2¾-inch	2¾	2⅛	1⅜	$\frac{11}{16}$

The use of molding is now generally restricted to the repair of installations originally constructed on the method. It is practically prohibited in the present policy of eliminating all wood from the permanent construction of the ship to minimize the risk of fire in action.

As a system it is inconvenient and objectionable for a variety of reasons, the chief of which are the following:

The large number of holes to be drilled and tapped, every 12 inches of length, to secure the backing strip. The drilling of beams for a passage for the wire, detracting from the beam strength; each hole drilled must also be carefully bushed with hard rubber. Changes of direction, or crosses, must be made by mitered joints, necessitating laborious and slow joiner work. No watertightness is assured except at connections, the mitered joints, capping, and fit at beams, leak; as the insulation afforded depends entirely upon keeping the molding dry, leakages through deck tubes readily introduces salt water. Many lengths of molding have been taken from ships which were charred through by a neighboring steam pipe, bake oven, galley, etc.; the carbon formed is not only a good conductor but is very hygroscopic; fireproofed woods are usually poor insulators, and corrode metal fastenings.

Molding is only fairly strong; it affords little protection to the wire from rough usage in fire-rooms or coal-bunkers, as it is easily torn down; it must follow the metal surfaces and cannot be run "flying." Where piping or some particular device requires much space up and down an engine- or fire-room bulkhead, the wiring must be led through to the opposite side, and generally into a coal-bunker; in these fire-room and coal-bunker locations, also subjected to clouds of dust and ashes, the use of molding has proved inadmissible.

Molding is sometimes permitted in quarters which are outside the watertight system of the ship; as the limits of the watertight system are generally defined to include all the ship construc-

tion below the stability (main) deck the use would be restricted to the upper deck cabins or wardrooms; it is also seen on some constructions where the wiring is run on insulators.

Conduit.—The types of conduit specified are: Steel, enameled; brass, enameled, flexible. Specimens of the first and third are shown in Fig. 33. There are in use, also, the *iron armored* or *lined conduit,* and a *flexible* type consisting of covered rubber hose.

Steel, enameled, and *brass, enameled,* conduit (*G,* Fig. 33) conform in their metal construction to the dimensions for commercially standard steam, gas, and water pipes. On the dimensions of the following table 0.02 of an inch is allowed for manufacturing and loss of thickness in cleaning:

I. P. S.	Outside diameter.	Thickness of wall.	Inside diameter.	No. of threads per inch.
Inches	Inches.	Inches.	Inches.	
½	0.840	0.110	0.620	14
¾	1.050	0.115	0.820	14
1	1.315	0.135	1.045	11½
1¼	1.660	0.140	1.380	11½
1½	1.900	0.145	1.610	11½

Steel conduit is bought in lengths of 10 feet; brass in lengths of 12 feet.

Each length is threaded with a right-handed pipe-thread at each end, and one end of each length is supplied with a standard right-handed coupling of the same metal as the conduit length to which it is attached.

The interior surface of enameled conduit should be smooth and free from burs or fins; the bores must not be diminished in cutting; all ends should be faced square and the inner edges slightly beveled. The enamel is to be of not less than three coats, and is baked on, inside and out; Sabin's baking enamel is preferred for the purpose.

Steel conduit is used for the general installation throughout the ship. Brass conduit is used, generally speaking, in locations where the use of steel is undesirable, such as magazines, shell-rooms, ammunition-rooms, including their connections and approaches (*steel is now commonly used, however*); about (if near) compasses, especially the standard compass.

Iron-armored (lined) conduit consists of a wrought-iron pipe lined with a bitumenized paper tube 1/16 inch in thickness; a

light cotton sheeting lining is sometimes placed between the pipe and the paper.

The type is not now carried in stock and is not replaced.

Flexible conduit (H, Fig. 33) consists of a spiral of insulated fiber over which is wound a heavy rubber friction tape; both are covered with a continuous woven jacket of cotton which is saturated with insulating compound and sprinkled with powdered mica. The particulars are tabulated as follows:

Inside diameter. Inches.	Outside diameter. Inches.	Feet to coil.	Pounds per foot.
½	¾	200	0.125
⅝	⅞	200	0.140
¾	1	150	0.175
1	1¼	100	0.250
1¼	1½	100	0.280

For repairs on board ship 1½-inch hose answers very well; the best for the purpose is the double cotton-jacketed hose (*I*, Fig. 33).

The use of flexible conduit is confined to runs of wiring where the conduit will be subjected to a twisting strain, such as those leading to turret lights and apparatus. It is rarely used as the twisting can be accommodated by leading between boxes on the turret spindle, in other cases jacketed hose is preferable. In latest practice flexible conduit has entirely disappeared.

Conduit Fittings.—The fittings necessary to connect up a line of conduit conform in size to the conduits with which they are to be used; those for steel, enameled, conduit, unless specifically prescribed, are of steel, wrought iron, malleable iron, or cast iron, accordingly as the particular material is used in commercial practice for commercially standard pipes; those for brass, enameled, conduit are of the "beaded malleable" pattern.

Elbows (*A*, Fig. 34) are made of conduit, are bent 90°, in equal legs, and pipe-threaded at each end, *externally*.

I. P. S. Inches.	Radius outside. Inches.	To fit in square of side. Inches.
½	5 to 5½	7¼
¾	5½ to 6	8½
1	6 to 7	10
1¼	7½ to 8	11⅜
1½	9 to 10	13⅝

Outlet elbows, 90°, are constructed of the same material as *elbows* and are similar in appearance to those used for steam pipes; they are threaded *internally*, and are of the following sizes: Iron-pipe size, ½ inch, ¾ inch, 1 inch, 1¼ inch.

Outlet elbows, 45°, differ from *outlet elbows*, 90°, only in the angle of the bend, and are of the same iron-pipe sizes.

Long elbows (*B*, Fig. 34) are made of conduit and are bent 90° in unequal legs, externally pipe-threaded at each end.

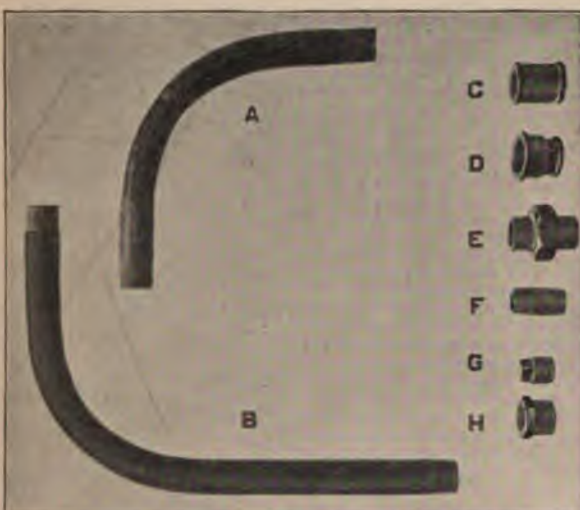


FIG. 34.—Types of conduit fittings.

I. P. S. Inches.	Radius outside. Inches.	To fit in rectangle side. Inches.
½	5 to 5½	10⅞ by 7¼
¾	5½ to 6	12 by 8½
1	6 to 7	13¼ by 10
1¼	7½ to 8	15⅝ by 11⅜
1½	9 to 10	17⅞ by 13⅝

Couplings, plain (*C*, Fig. 34), are the pipe couplings to connect up the lengths of conduit and are continuously threaded internally. The sizes are: Iron pipe size, ½ inch, ¾ inch, 1 inch, 1¼ inch, 1½ inch.

The couplings may be *right-handed*, the thread running continuously from end to end, used for the general use of connecting up a line of pipe, and in which the coupling is first screwed to

one length and the next length screwed into the coupling; or *right- and left-handed,* the thread being cut *right-handed* at one end and *left-handed* at the other, used for connecting up lengths of piping where it may be desirable to open up without taking down the line from either or both ends. The difference in use between the right and left coupling and a union is that unions are used when the pipe cannot be drawn (sprung) back, right and left couplings necessitate a separation of the ends by a full inch.

Couplings, reducing (*D*, Fig. 34), are similar to those used with commercial pipe, and are used when a change in size of pipe is desirable; they are threaded right-handedly, internally, and accomplish the following changes:

Iron pipe size: ¾ inch to ½ inch, 1 inch to ¾ inch, 1¼ inch to 1 inch, 1½ inch to 1¼ inch.

Unions (*E*, Fig. 34) are similar to commercial pipe unions, but the lip is ground off to facilitate springing apart the two lengths of conduit. They are used for separating a line of piping in lieu of *right- and left-handed* couplings in locations where the pipe cannot be forced back and the ends must be separated across the pipe end-faces.

Nipples (*F*, Fig. 34) are made of enameled conduit and are externally threaded at each end; there are occasions requiring threading for the entire length. They are used as the connection of the conduit to various devices and as fitting pieces in finishing runs.

Both ends R. H. threads			One end R. H. and one L. H.		
	Lengths.			Lengths.	
I. P. S. Inches.	Short.	Long.	I. P. S. Inches.	Short.	Long.
½	1½	3½	½	1½	3½
¾	2	3½	¾	2	3½
1	2	4	1	2	4
1¼	2½	4½	1¼	2½	4½
1½	2½	4½	1½	2½	4½

Plugs (*G*, Fig. 34) are similar to commercial pipe plugs, and are right-handed; the sizes are: Iron-pipe size, ½ inch, ¾ inch, 1 inch, 1¼ inch, 1½ inch.

They are used for closing up the unused openings of appliances.

Bushes (*H*, Fig. 34) are similar to commercial pipe bushes.

The standard sizes are: Iron-pipe size, ¾ inch to ½ inch, 1 inch to ¾ inch, 1¼ inch to 1 inch, 1½ inch to 1¼ inch..

They are used where a smaller pipe is to be fitted into a fitting already tapped for a larger; they differ from a reducing coupling in that they are threaded both externally and internally.

Conduit should be used exclusively for ducts. Some of its advantages are:

The time and labor of installation is limited to drilling, without tapping, for hangers at beams only, or for straps at four- or five-foot intervals along flat surfaces, such as bulkheads, decks, etc.; changes of direction are made by bends or elbows which, except in long bends, require no fastening; one length joins the next through the commercial coupling. The drilled holes in beams and flat surfaces detract less from the metal strength than those for molding. It is watertight from the nature of the continuity of pipe joints and the screw joints at boxes, fixtures, etc. It is strong; it affords ample protection to the wiring where exposed to rough usage; it can be utilized as the pendant or support of a box or fixture; it can be bent clear of apparatus which interferes; it is fireproof; it affords good insulation as both pipe surfaces are covered with a good insulating material. The principal objection to conduit is its weight. In regard to the statement as to insulation, a qualification must be applied that the conduit be drained and dry; experiments show that if the dry enamel layer be examined with an exploring wire it will easily stand 2000 volts and the insulation resistance be high. If one end of a piece of conduit be embedded in paraffin and the tube be filled with salt or acidulated water, on inserting a wire into the water and again touching the metal of the conduit a low resistance or dead ground will result, showing that however well the enamel be put on, there are still minute interstices which affect or vitiate the insulating properties.

Insulators.—Insulators are made of glazed porcelain and a number, one for each wire run, are assembled together as shown in *A*, Fig. 35, which is the especial arrangement for lines of the larger sizes of wiring which are to be run along flat surfaces such as under decks and on bulkheads. The blocks of this assembly are square, in two parts, and are scored at each end for the securing bolts. The securing bolts are riveted into a base strip of bar metal whose width is the thickness of the insulator block, and

their outer end is threaded for the nut which is set up on a round washer. Between the blocks and the metal base, and along the outer surface of the blocks, *and underneath the washers, is placed a strip of 1/16-inch cloth-insertion sheet-rubber packing,* which serves as a cushion against shock and gives a more even distribution of stress. At either end of the block assembly a post support is riveted to the metal base strip and finished at the outer end with thread, nut, and washer. The surface over which the base strip is to rest is tapped for two bolts which secure the assembly in place.

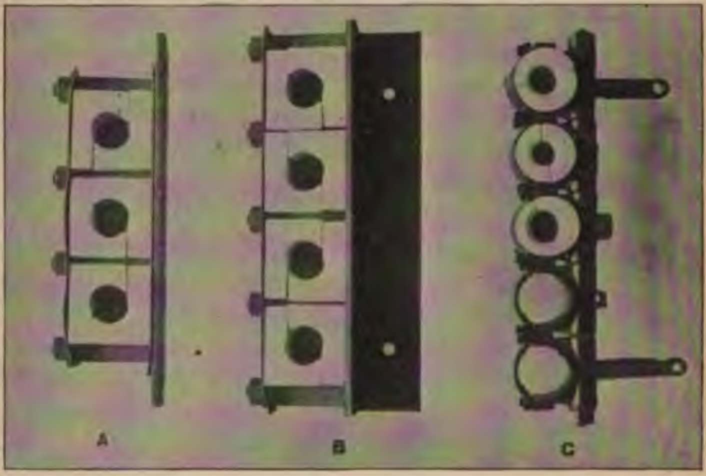


FIG. 35.—Methods of insulator installation.

B (Fig. 35) shows another assembly of square insulators erected on an angle bar; this arrangement is used where the assembly is to attach to the angle side of bulkheads, beams, or projections which afford a flat surface for bolting.

C (Fig. 35) shows an assembly of round insulators, a convenient arrangement for attaching to beams, etc. One hanger has a flat surface for working next a single bulb beam, the other is curved and is of the type for working over double bulb beams; for channel beams a flat strap only is necessary. This assembly consists of a bar threaded at each end, over which the sleeves carrying the insulators and hangers are slipped, the assembly being set up by a nut and washer at the ends of the bar. The

strap for holding the insulator in the sleeve is divided, the insulator being secured by a flanged-containing strap which is set up on each side by a screw tapping into the sleeve.

As the wire is strung along on the insulators it is left uncovered except in exposed places, where it is sometimes covered by a galvanized sheet-iron cover, bent to the dimensions rectangularly, flanged and secured by screws; the different lengths of covering are not fastened together, to facilitate removal.

The chief advantage of running wire on insulators is the saving of weight and cost as compared with either conduit or molding. If a sheet metal covering is provided, it is only used where the wire is especially exposed to mechanical injury. The method would not suffice for fire and engine rooms, store-rooms, or in fact any location under the protective deck, except wing pas-

Fig. 36.—Feeder junction box for conduit.

sages, tiller or steering rooms and sections of a platform deck; above the protective deck it is not advisable, except perhaps in quarters, owing to the likelihood of injury to the wire from gun gear, etc., and particularly from thoughtless handling which would stretch the wire or break its insulation. The use of sheet metal covering is probably unsanitary, by reason of the lodgement of dust and coal dirt, and as forming a retreat for vermin, especially that ship-pest, cock-roaches.

Box Types

The use of boxes arises from the necessity of protecting, watertighting, and fireproofing circuit connections, and box types for other than interior communication lines receive their name from the particular method of connection desired as determined by the interior fitting which the box encloses.

All boxes consist of two parts, the *box proper* and an *interior fitting*.

The Box Proper.—That for conduit (Fig. 36) consists of a

cast composition shell and a cover. The sides and ends of the shell are reinforced by bosses, cast in one with the shell, which are drilled and tapped for the size of conduit appropriate to the size of the wire which is to be led in; the extra thickness of the bosses gives the length of thread required for a strong, good joint.

On the inner bottom of the shell are cast small bosses which are tapped for the screws which secure the interior fitting in place. To insulate the interior fitting and screws, if loosened, from the metal of the shell, the interior of the shell should be painted with Sabin's enamel (" Sabined ") ; a sheet of mica, 25 mils thick, and of slightly greater dimensions than the insulating block of the interior fitting, is fitted over the bottom bosses; the mica also affords a slight cushioning effect against shock, and affords a long surface of insulation.

FIG. 37.—Feeder junction box for molding.

The outer edges of the shell are tapped for the prescribed number of screws which will hold the cover securely without warping.

In the box walls are drilled and tapped the screw wells, in which are driven the screws which secure the completed appliance at its location in the ship. The nature of the pipe assembly is sufficient in most cases to hold the box in position without the screws in the screw wells; *to preserve watertightness, the screw well masses are never drilled unless the appliance must be secured by the screws.*

For installation where molding is the duct the type of box for similar use as Fig. 36) colloquially known as the " Navy Standard Box" is that shown in Fig. 37. The difference is that stuffing tubes are inserted at the sides and ends of the box in place of the bosses shown for the conduit box (Fig. 36). The stuffing tubes are threaded for their entire length and are screwed

into the wall of the box and braised. On the outer end of the stuffing tube is a gland whose office is to set up the conical rubber gasket which packs the wire watertight; the stuffing tubes are reamed to take the conical shape of the gasket, and inside the gland is a small brass washer ring *without which it would be impracticable to turn the gland against the friction of the gasket.* In other details the box for molding and the box for conduit are alike and both types are made for all the varieties; the covers are identical.

The box cover is sawed out of sheet brass. The screw holes are drilled by jig. The cover is cut for the apertures adapted to the particular name of box. The whole of the inner side of the cover is lined with cloth insertion sheet rubber packing, cemented on to prevent stripping when the cover is removed. The packing takes on the box edges and closes the joint watertight.

The Interior Fitting.—While each type of box appliance has an interior fitting peculiar to itself, the following are general features common to all interior fittings (except those for interior communication lines).

I. The insulating block on which the circuit connections are assembled is made of vitreous, unglazed porcelain.

II. The interior fittings of all boxes of the *same name* whether for molding or conduit are identical.

III. All current carrying parts of interior fittings are of copper (usually stampings) of 96 per cent conductivity.

IV. All current carrying parts must be exposed and not embedded in the porcelain.

The few exceptions to these general rules are noted under the respective cases.

The names of the different types of box on other than interior communication lines are:

Junction box.
Distribution box.
Switch.
Receptacle.
Switch and receptacle.

The Junction Box.

This type, commercially known as a cut-out, affords the means of tapping off current from the feeders leading from the switchboard to the mains and sub-mains, or from these latter to the branches which feed the outlets for lights, etc.

There are four classes of junction boxes:

The Feeder Junction Box (F. J. B.).

The Main Junction Box (M. J. B.).

The 4-Way Junction Box, or Branch Junction Box, 4-Way (B. J. B. 4).

The 3-Way Junction Box, or Branch Junction Box, 3-Way (B. J. B. 3).

All junction box interior fittings have their porcelains of dimensions, least, 3 9/16 by 1 13/16 by ½ inch; the clearance holes for securing by No. 6 screws to the bosses in the bottom of the box are 3¼ inches between centers. The rule previously to 1902 was 3⅛ inches; the new rule is established in order to have all porcelains interchangeable, those for conduit boxes having been established at 3¼ inches. The old type of porcelain (3⅛) can be used on a 3¼-inch center by slotting away.

All current carrying parts of the interior fitting which are of opposite polarity are to be separated from each other and from the walls of the box by at least ⅛ inch.

Feeder Junction Box.—Feeder junction boxes are for tapping off current from the feeders leading from the switchboard to mains and sub-mains only and are always made three-way, one single (or double) entrance and one single (or double) outlet for the feeder at the ends, and an outlet for the main, or sub-main, at the side.

There are two sizes of standard conduit feeder box; one which is known as Feeder Junction Box for Double Conduit, and to be installed when the wire size of the feeder is above 60,000 cm. and up to 150,000 cm.; the other when the wire size is 60,000 cm. (30,000 cm. for twin conductor) or under; the governing cause of difference in type being the number of conduits necessary for the wire size of the feeder, two conduits for the larger sizes and one for the smaller.

Figure 36 shows the smaller size of box for conduit work. The larger differs in having two bosses on the ends, one for each of the legs of the feeder, positive and negative; small size

wires can be run in one conduit, tapping into the smaller size box. The screw wells are tapped near the corners of the box and are sunk into the walls without masses. The cover is secured by six screws, one of which takes the chain of the screw cap.

The screw cap is lined with cloth insertion sheet rubber packing cemented to the inner side of the top, and is recessed for the wrench; the chain is held by a round-head-rivet post.

The interior fitting is a double-pole, single-branch block rectangular in shape.

One through circuit connection is led straight, the other is bent in to avoid the two side connections, all are secured to the porcelain by screws whose bottom ends are in recesses of the block. In one with each connector and side connector is a vertical

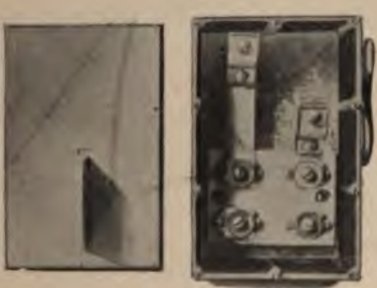


FIG. 38.—Special feeder junction box, conduit.

flanged projection on which rests a mica cup; the office of the cup is to prevent the spreading of the metal when a fuse blows, the cup protecting all of the fitting except the fuses and their contact screws. Only the side leads are fused, that is, there is no break in the feeder line. The fuses are of the copper tipped commercial type and bent as shown.

The two small copper connectors shown at the top of the figure are supplied to bridge across the fuse gap, to make through connections to the main or sub-main, when the branched wire size is to remain the same and does not require fusing, or when a sharp branch in a feeder line is to be made for which pipe bends will not answer. The copper connectors are secured to the fuse contact screws; the fuse and mica cup are then omitted. The wires are secured to the connectors by a clamping, binding strap with recess in both strap and connector.

Special Feeder Junction Box, or Feeder Box for large currents.

This type, shown in Fig. 38, is for use on heavy power circuits carrying from 400 to 500 amperes. It is much larger than other types of feeder box and has a large boss at one end, and two on each side near the end, to be tapped for leading in the wiring. The bottom of the box is covered with ⅛-inch micanite as insulation to the interior fitting.

The interior fitting block of porcelain is held to bosses on the interior bottom of the box by two screws, and to the block are secured four current carrying parts of copper—ordinarily of cast copper—having a sufficient cross-sectional area for carrying 450 to 500 amperes; the two contacts, near the leading in end of the box are copper blocks, secured to the porcelain by screws, and having binding straps for securing the wire; the other two contacts are longer connectors and curved that the wiring may pass well clear when entering to pass through the side bosses. The two sets of contacts are separated by one inch and arrangement is afforded for bridging the gap by a heavy (dynamo type of) fuse. To the inside cover of the box is secured a micanite plate which extends down between the fuses of the box to prevent arcing across. The cover is lined with cloth insertion sheet rubber packing.

[NOTE 8.—Micanite is a term used commercially for assemblages of mica in cement, it being impracticable to obtain mica in requisite thickness. One method of construction is to stamp out thin sheets of mica into convenient shapes and area, these are then built up with cement and pressed into a slab of desired thickness which can be cut or machined. The construction does not absorb moisture and is but slightly affected by oil, giving good insulating properties.]

Search-Light, or Main Junction Box.—This box is rarely used. It was intended as a through connection, to avoid splicing, in a long feeder line when the feeder wire had to be cut by reason of mechanical difficulties or probable injury in drawing; pulling sleeves obviate cutting even the longest feeder and the small carrying capacity of the box renders it inadvisable for the purpose. The box has sometimes been used on a search-light line for connecting in the search-light leads, but it is not necessary, except in the cases of alterations where a detour is made, necessitating the insertion of an extra length of conductor.

The conduit type is shown in Fig. 39. The box is similar to the feeder box but without a side boss.

The cover is without opening and held by six screws.

The interior fitting has two through connectors with binding straps at either end.

Branch Junction Box.—The branch junction box, 4-way or 3-way, is for tapping off current from mains or sub-mains to

FIG. 39.—Main junction box, conduit.

the branches leading to outlets for lights, etc., only. The wires of the mains (or sub-mains) are led in at the ends and the branches led in at the side; if it is necessary to branch in on both sides a 4-way box is installed, if on one side only, a 3-way. It is intended that the side leads shall be for single wires of not greater size than No. 14 B. & S. G. (4017 cm.).

The conduit, 4-way type, is shown in Fig. 40. The 3-way

FIG. 40.—4-way branch junction box, conduit.

differs in having a boss on but one side instead of the two sides as shown.

The cover and wrench are the same as for the smaller size of Feeder Box; the screw wells are similar.

The interior fitting has two through connectors for the wire main with binding straps at each end. The side connectors are run across the block so that either or both sides may be branched.

On each through and side connection is a vertical to which is screwed a clip, protected by a U-shaped guard, the clip and guard assembled on the same screw. Into these clips are pressed the glass tube fuses for the branches. The cross-section of the current carrying parts is 30,000 cm. The clips are of phosphor bronze.

Distribution Box.—The object of the distribution box is to avoid the installation of so many branch junction boxes on a main in those locations (such as fire and engine rooms) where it is practicable to distribute to a number of outlets in nearby

FIG. 41.—8-way distribution box (cover not shown).

locations from one central point. The distribution box collects these various branches into one box and thus simplifies access to connections and for fusing.

Distribution boxes are classed by their number of branches into two types, the 8-way and the 12-way box, the difference in construction being mainly that of length.

The boxes have usually been installed at the end of a main only, but a through run is now practiced, by casting a boss on both ends.

The 8-way box is shown in Fig. 41.

The end boss (a boss in each end in latest designs) is tapped for one-inch conduit to carry in a maximum wire size of 30,000

cm. conductor (usually twin conductors) for the main, the side taps—4 each side—are for ½-inch conduit for a maximum wire size of 4107 cm. twin conductor. The box is secured, if necessary, through four screw wells, in masses, in the corners. In the bottom of the box are four tapped bosses for the screws securing the interior fitting.

The cover is secured with twelve screws and is cut, for an opening by two plates, hinged together and held to the cover by screws; the plates are lined with cloth-insertion sheet-rubber packing, cemented on.

The interior fitting consists of a slate panel, on which are installed two copper bus bars of 30,000 cm. cross- section, leading to the end boss of the box, and ending in two contact screws which secure the binding plates for the wires of the main. Extending towards the sides of the box, and secured to the bus bars, are eight copper connectors for feeding the branches; on the outer edge of the slate base, across the fuse gap, are other copper connectors with contact screws for the branch wires; both sets of connectors are fitted with clips and guards identical with those used in the branch junction boxes. The fuse gaps are bridged with the standard glass-tube fuses.

In assembling, an oil-filled, hard wood block is placed between the slate base and the bottom bosses of the block.

The type of box has the disadvantage that the branch taps are so close together that the conduit must be bent to accommodate the individual switch boxes which are grouped near the distribution box.

Switches.

There are five types of switches (and one special switch) of which all except the 5-ampere are double-pole; their office is to make or break, cut in or cut out, the electrical supply of the lines which they control.

100-Ampere Double-Pole Switch.—This heavy switch is installed on feeder lines, on inter-connections between feeders and on search-light leads at the base of the projector, when the switch is not self-contained. The conduit type is shown in Fig. 42.

The box has a boss at each end only, capable of taking a conduit of 1½-inch pipe size. Four screw-well masses are provided at the corners.

In the bottom of the box are two bosses for securing the interior fitting.

The cover is pierced at the center for the tube forming the entrance for the switch handle shown; the entrance is closed at other times by the standard screw cap.

The interior fitting has a connector at each corner, one end of which is fitted with a binding strap for the entering wires; the other end is bent in towards the center and ends in a tongue which can be caught between the clip plates on the switch barrel, embodying the general principle of a knife switch at each tongue. Two tongues, diagonally opposite, are bent down into the recess of the block to separate the clip plates of opposite polarity by one-half inch.

FIG. 42.—100-ampere switch, conduit.

The switch barrel assembly consists of a central steel stem fitting in a square base, the base being secured on the bottom of the block by a nut. On the shoulder of the square base is slipped a hard rubber insulating washer, above which are the lower set of clip plates, separated from each other by a copper washer 1/8 inch thick. Above this pair of clip plates is a second set of same construction separated from the former by a hard-rubber washer 1/4 inch thick. A hard-rubber washer at the top and a brass follower, secured by four through screws, completes the assembly.

The switch stem is insulated from current carrying parts by hard-rubber bushings.

The switch is made quick-break, to shorten the time interval of arcing, by two steel springs, bearing against brass plates, sunk in deep slots in the block.

The clip plates cross the fitting diagonally, and hence the polarity of corresponding wires at the two ends of the box will be different, or the polarity will be "crossed" in the box.

The switch is turned by a through pin on the switch stem which fits a corresponding score on the base of the hollow stem switch handle.

50-Ampere Switch, Double-Pole, Single Throw.—This large switch replaces the 100-ampere switch when a current of about 50 amperes is to be the maximum to be carried on the main. The conduit type is shown in Fig. 43.

The box has four screw well masses at the corners and end bosses. The cover is cut in the center for the switch handle and closed with the standard cap.

The interior fitting is a modification of that for the 100-ampere switch and crosses the polarity. Two of the four corner connectors are short and are bent down into the block recess, with a tongue to take between the clip plates at this end, and binding

FIG. 43.—50-ampere switch, conduit.

straps at the other. Two connectors are long with binding straps but have, instead of tongues, a straight copper connector ending in a punched washer and which forms part of the switch barrel assembly.

The stem of the switch barrel is similar to that of the 100-ampere switch, the square base and steel spring, which make the quick-break, being smaller. On the shoulder of the square base is an insulating hard-rubber ring, above which is placed one of the lower clip plates, next come the washer ends of the long connectors, then the second of the lower clip plates; each clip plate is made in two leaves to reduce stiffness. The upper clip plates are similar to the lower and are separated from them by a porcelain washer ¼ inch thick. A hard-rubber washer and a copper follower completes the assembly. The switch handle and through pin are the same as for the 100-ampere.

The punchings in the washer ends of the long connections

provide collars in which the barrel turns and which secure it in place. Stops on these washers limit the throw of the clip plates.

50-Ampere Switch, Double-Pole, Double-Throw.—This switch, commonly known as the Transfer Switch, is a modification of the 50-ampere, single-throw, switch. It is installed to connect to a main carrying about 50-amperes when the main is to be fed from either the lighting or battle circuits (such as a main for signals, running lights, etc.) and is to be connected to both. The conduit type is shown in Fig. 44.

The box has a boss on one side but is otherwise similar to that for the 50-ampere, single-throw.

There are four corner connectors in the interior fitting which are similar to the short connectors of the 50-ampere, single-

FIG. 44.—50-ampere transfer switch, conduit.

throw, switch. The two sets of two-leaf clip plates and the switch barrel are assembled similarly to those of the 50-ampere, single-throw, except that, instead of the long connectors, there are two side connectors with binding straps which have their end washer rings assembled in similarly to those of the long connectors; the washer rings have no stops and the clip plates can be swung completely around. The polarity is crossed in the connections.

Special Switch, Double-pole, Double-throw.—This large switch, shown in Fig. 45, is not carried in stock. It is a transfer switch designed to carry the heavy load of 800 amperes for use in transferring power loads for the 12-inch or 13-inch turrets from the circuits of the forward to the after dynamo room and *vice versa;* the small number used in any installation are made up as required.

The box is a built-up box of ⅛-inch galvanized sheet iron flanged at the lower end for securing to a bottom plate of iron

18¾ inches x 14⅛ inches x 5/16 inches thick, and provided with a hinged cover and a hasp for a padlock. The side of the box in the wake of the terminals has openings sufficiently large to admit the large wires.

All parts of the switch proper are of hard drawn copper; pins are of phosphor bronze; and screws and washers of brass.

Overall dimensions of the box are 18¾ inches x 14½ inches x 11 inches (high).

The poles of the switch are made up of two blades each, 2 inches by 7⅜ inches by 7/32 inch, secured to hinge posts, and to blade caps which are secured to a hard rubber yoke. On either side of the yoke is a handle at right angles to the blade of the switch. There are two clips per blade, let in and brazed to

FIG. 45.—800-ampere special (transfer) switch, conduit.

foot-pieces; there is a separating piece between the clips, which acts as a stop for the blades. The foot pieces are mounted on a slate base and secured from the under side with two brass machine screws.

The slate base is secured through two strips of sheet rubber packing to two wrought-iron straps; these straps are bent into an inverted U-shape, and secured to the bottom plate of the box by hexagonal brass tap bolts.

The foot-pieces for one pole of the switch are slotted to a depth of 1 3/16 inches to receive the shanks of one set of terminals; the foot-pieces for the other pole of the switch are connected to busses located below the slate base. These busses are made in two pieces, separated from the slate base and from each other, and are secured to the studs by hexagonal nuts. The shanks of another set of terminals at the other end of the busses act as separating pieces.

The terminals are located on one side of the box; the large end terminals are for the bus wires from either distribution room, and the four small center terminals are for the circuit leads around the turret.

25-Ampere Switch, Double-pole.—This snap switch is a line switch for mains or leads not expected to carry more than 25 amperes. The conduit type is shown in Fig. 46.

Four screw well masses are located in the box ends inside of the holes for the cover screws. There is but one boss at each end.

The cover is held by four screws and is cut for the entrance of the switch handle, the entrance being closed by a standard cap. The entrance is off the box center.

FIG. 46.—25-ampere switch, conduit.

The switch stem of the interior fitting extends up through the block and switch barrel; on its lower end is riveted a brass plate carrying diametrically opposite pins on which small brass rollers journal; the rollers run on a brass ratchet in the bottom of the porcelain block, fitted over a ratchet in the porcelain corresponding in breaks to the breaks on the porcelain ratchet of the switch barrel. The central part of the stem is flattened to take the rectangular section of the interior of the switch barrel and drive it.

The switch barrel is a porcelain cylinder, part of whose boring is rectangular; the cylinder surface is molded to form four ratchet teeth, two of which, diametrically opposite, are surfaced with copper sheet held by solder, the other two teeth are blank porcelain.

The line connectors are two long and two short, ending in binding straps. The long connectors are on a raised part of the

block and end in a vertical flange to which is riveted a snap finger bent round to bear on the curve of the ratchet teeth of the switch barrel. The short connectors are similarly fitted but are flanged down into a recess of the block to take the snap finger.

As the switch is snapped from a ratchet tooth, one long connector and one short connector on the same side of the block are either connected through the copper plates on the switch barrel or are insulated from each other on the blank teeth.

The polarity of the line is not crossed in the switch.

5-Ampere Switch, Single-pole.—This snap switch is the one generally inserted in lines branched to outlets for controlling the individual outlet, provided no greater current than 5 amperes is

FIG. 47.—5-ampere switch, conduit.

to flow. The conduit type is shown in Fig. 47. (When the switch is to be at the end of a pipe, the type of box shell is similar to that shown in Fig. 49.)

There are but two screw wells located at the end which is fitted for the two bosses. The cover is held by four screws. The switch handle remains permanently with each box, and, to prevent water from entering, a rubber gasket and stuffing box are fitted to the cover, and assembled together by a standard cap, drilled to take the switch stem.

The switch being single-pole, the connectors are connected together by a copper plate. The connectors are of brass; one leads to the copper plate and thence towards the switch barrel, where a spring finger similar to one of the fingers for the 25-ampere switch, is secured by a screw; the other connector is short and secures a similar finger.

The switch barrel, is of porcelain, similar to but shorter than that for the 25-ampere switch. Over the barrel is slipped a

copper stamping which fits two diametrically opposite teeth of the barrel ratchet, to make and break connection with the connector fingers. The brass switch stem has rollers and ratchets beneath the block identical with those of the 25-ampere switch.

The switch barrel is held down by a steel spring which shoulders against a brass sleeve on the stem above the spring. Above the sleeve is a pin by which the thumb nut drives. The thumb nut is a casting having a small ratchet at its bottom face, and a spring in the core which takes against the head of the screw securing the thumb nut to the stem. This arrangement prevents turning the switch in the wrong direction and thereby bending the fingers; the thumb nut will spring up and back if the ratchet is turned left-handedly, and only the handle will turn.

FIG. 48.—25-ampere switch and receptacle, conduit.

Receptacles.

The type is designed for the purpose of providing an outlet into which the wiring of movable fixtures can be plugged, for current supply, by means of one of the standard attachment plugs.

25-Ampere, Switch and Receptacle, Double-pole.—The conduit type is shown in Fig. 48.

The box has four screw wells, and with one boss at the end.

The cover is pierced for three entrances, two near the ends for the two *25-ampere attachment plugs,* and one near the center for the switch handle.

The block is the same as that for the 25-ampere switch. The difference for the remainder of the interior fitting and that of the 25-ampere switch is that the long connectors have a contact clip for the attachment plug instead of a binding strap. This contact clip is of phosphor bronze; the sides are bent slightly

out of rectangle and their upper ends are turned in to give a spring action in holding the plug.

5-Ampere Switch and Receptacle.—The conduit type is shown in Fig. 49.

The box is the same as for the 5-ampere switch excepting that the cover has an additional aperture for inserting the *5-ampere attachment plug*. (See description of 25-ampere attachment plug

FIG. 49.—5-ampere switch and receptacle, conduit.

and 5-ampere attachment plug for the important electrical difference in construction. This difference has been sometimes overlooked in fitting double conductor, plain, for fixtures.)

The block and switch are the same as for the 5-ampere switch; the difference for the remainder of the interior fitting and that of the 25-ampere switch is that the long connectors are not con-

FIG. 50.—5-ampere receptacle, conduit.

nected together by a copper plate but end in one vertical phosphor bronze piece like one of the 25-ampere switch-and-receptacle contact clips. The 5-ampere attachment plug requires a gap and not a connection between the clips.

5-Ampere Receptacle.—The receptacle is for use where the switch combination is not required. The conduit type is shown in Fig. 50. The box is the same as for that for the 5-ampere

switch and receptacle except that the box cover has but one aperture, which is fitted with a cap. The switch parts of the 5-ampere switch and receptacle are omitted in the interior fitting; the straight brass connectors are connected through the box to the same type of contact clips as in the 5-ampere switch and receptacle; the other ends of the long connectors end in a contact screw.

The 5-Ampere Double Receptacle.—The conduit type is shown in Fig. 51, and is, in effect, two 5-ampere receptacles combined. The difference between this receptacle and the 5-ampere receptacle is that there is a set of clips at each end of the interior fitting instead of at one end only, and the box cover is cut with two apertures, for the insertion of two 5-ampere attachment plugs, each aperture being provided with a standard cap.

FIG. 51.

FIG. 52.

FIG. 51.—5-ampere double receptacle, conduit.
FIG. 52.—5-ampere switch, with hood, conduit.

The double receptacle is installed in staterooms for the two outlets required for one fan and one desk light, and takes the place of non-watertight receptacles, key and keyless.

5-Ampere Switch, Single-pole, with Hood.

25-Ampere Double-pole Switch and Receptacle, with Hood.

5-Ampere Switch and Receptacle, with Hood.

The distinction between these three types and the types which have been previously explained (without the hood) is merely in the shape of the box shell, of which a type is shown in Fig. 52.

The top of this box is curved into a semi-circle and is flanged out over the top to cover the face of the appliance and protect

the handle from loose gear about decks, or when the appliance is likely to be stepped on about hatches, or from the weather on uncovered decks. The box cover is cut to fit the extended and rounded shape of the top of the box shell, otherwise it is similar to those for the unhooded appliances.

Box Types for Interior Communication Circuits.

Connection Boxes.—Connection boxes are of four sizes, known as 20-wire, 40-wire, 60-wire, and 70-wire boxes. They afford a convenient means of branching out the interior communication leads, from the cable or from main wire leads, to the different locations in which a part of the wires are to be distributed or

FIG. 53.—Connection box, interior communication.

are to connect to interior communication apparatus, as bells, annunciators, etc. The box and fittings are shown in Fig. 53.

The box is of cast bronze composition and is secured in place through four screw wells. In the bottom are cast four long bosses, on which rest the interior fitting carrying the terminals.

The cover is plain and is watertighted by a cloth insertion sheet-rubber packing, which only covers a portion of the inside edge of the box, the packing being secured to the cover by tap screws and by the screws which hold the cover to the box shell. There are no pipe bosses on the outside of the box, but on the

inside of each box wall are bosses which are to be tapped to take the ends of the conduit.

The interior fitting is built up of micanite into an open square and drilled at the corners to be secured by screws to the bosses; the corners are cut away to fit inside of the screw well masses. On the four sides of the micanite are secured the plates to which the wire terminals are held by screws; the terminals are copper stampings bent into tubular shape at the ends that the wire end may be conveniently entered and soldered.

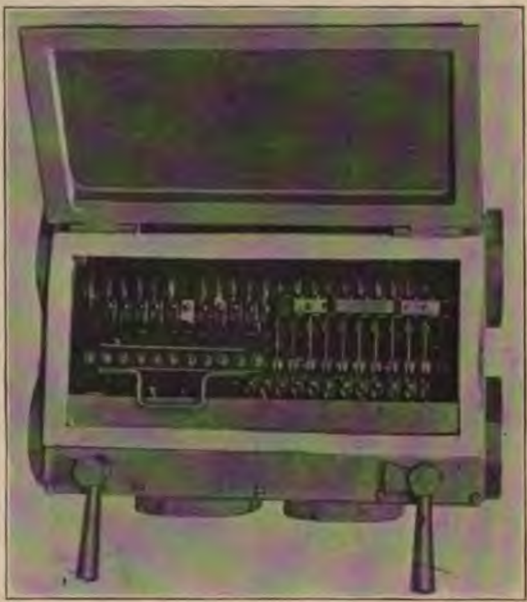


FIG. 54.—Action cut-out switch.

There are five plates on each side of the twenty-wire box, ten on each side of the forty-wire box, and fifteen on each side of the sixty-wire box, but the total number of connections can be increased by securing other terminals under the same screws, as in the case of several common returns. Necessary room is afforded in the bottom of the box for disposing of the slack of the conductors and the terminals are made sufficiently long to be bent down for convenience and as required. The number of the particular wire lead is stamped into the terminal by a die.

In the forty-wire box there are three bosses inside of each box wall, admitting of twelve conduits or box tubes, if required.

Cut-out Switch.—This switch (known as the Action Cut-out), is shown in Fig. 54; the size shown in the figure is for 22 wires. It combines in one appliance the means of cutting off a number of lines of interior communication which are to be used in action (and behind armor or other protection) from other parts of the same lines which are not required in action, and which latter from exposure to injury might occasion grounds or short circuits in the system.

The various uses of the switch are referred to under Installation.

The box is a composition casting. Bosses for the attachment of the stuffing tubes or conduits are located externally on the sides, to be tapped as required. Bosses are also cast internally on the sides, to be drilled to take the screws for securing the box in position when conduit is not installed.

Bosses are raised on the inner bottom and drilled and tapped to take the screws for holding the base.

The upper edges are tapped to take the cover screws, the corners being filleted and the bosses swelled out where the screws come between the corners.

The cover is of thick sheet brass with a central rectangular hole for ready access to the fitting.

Two lugs on the left hand edge form parts of hinges. On the right-hand side two inclined surfaces, called wedges, are cast which form part of the ready locking device for the cap. A cloth insertion sheet-rubber packing is inserted between the surface of the cap and the cover to watertight the appliance.

The cap is clamped by two handles which force the cap against the packing by pressure on the wedges in the same way as the dogs on a watertight door. The heavy extension of the handle prevents any loosening by jar.

On the inner surface of the bottom of the box is placed a micanite sheet to insulate the fitting and its screws from contact with the metal.

The interior fitting consists of a rectangular slate base on which are mounted a number of knife blade switches, single-throw, the blades being connected in sections to two or more common switch yokes. To each of these yokes is fastened an

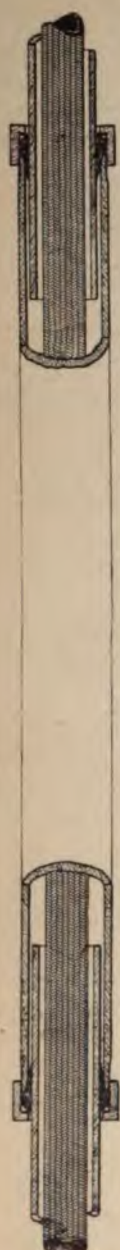


FIG. 55.—Pulling sleeve.

open switch handle which admits of the simultaneous opening or closing of all of its contacts, the cap being opened for the purpose.

Terminals, to which the conductors are soldered, are fitted to each switch terminal, space being allowed for stamping the individual wire numbers.

Allowance of space is made between either side of the switches and the sides of the box for the leading in of the wires.

Transfer Switch (Interior Communication).—This switch is ordinarily of similar construction to the cut-out switch. The main difference is that the switches are double-throw to permit alternative locations, such as a chart house and conning tower, to be connected to the same lines. Its convenience resides in reducing the number of cut-out switches which would be otherwise necessitated and preventing two being on at one time.

The Watertight Box and Pulling Sleeve.

These two appliances have no interior fitting and are not strictly boxes.

Watertight Box.—This box is installed on conduit lines near a deck or bulkhead to stop the flow of water which may have entered the conduit from any cause, such as covers or caps being left off of boxes, or from rupture of the conduit in action in a compartment which has been flooded, or from condensation.

There are two similar types shown in Fig. 69, one of which is employed when the appliance can be located close to the bulkhead. The second type is for use when the appliance must be located farther away from the bulkhead from interference of structure or apparatus; it is similar to the former type, differing in the length of stuffing tube to be employed.

The box is merely a casting, bottom hemi-cylindrical, with

cover for access. Within the box one end of the conduit is watertighted by gland and gasket in the usual way; the box surrounds the end and preserves a continuity of the conduit, and the removal of the cover permits access to the gland and gasket for setting up. The gasket set up, the conduit is protected from communication of water between compartments.

Pulling Sleeve.—This appliance is shown in section in Fig. 55. It satisfactorily replaces, and is much lighter than, the former pulling box, and also obviates cutting a long length of wire.

Over the conduit shown is placed a brass tube whose ends are threaded outside, and are beaded inside, to take a rubber gasket, which is set up by a gland against a brass washer. The sleeve is a convenient device for access to the wiring, the ends of the conduit being separated a good distance as shown; the pressure of

FIG. 56.—Terminal box for staterooms.

the gasket retains the sleeve in place; when drawing wire the gland is slacked and the sleeve slipped along the conduit out of the way.

The different particulars for different size sleeves are tabulated as follows:

For Conduit I. P. S.	Outside Diameter.	Inside Diameter.	L.	S.	D.	Gasket.	Weight Complete, lbs.
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.		
½	1¼	⅞	15	9	½	B-27	3.125
¾	1½	1 3/16	20	14	¾	A-34	4.375
1	1¾	1⅜	24	18	¾	F-42	7.500
1¼	2¼	1⅞	30	22	1	G-54	12.125
1½	2½	2	36	26	1⅛	J-61	21.250
2	3¼	2¾	40	30	1⅜	L-76	32.000

Terminal Box.

There are several sizes of this appliance which are used merely as a terminal base into which the wiring can be led and to which

some forms of appliance can be secured. In general they are similar to Fig. 56, but when several are to be assembled at the same place the box is made to include all in the same casting.

The type shown is that which has been used in staterooms for mounting push buttons for the bell circuits, and the switch for the lighting circuit. The conduits enter in an upper surface not shown in the figure.

Non-watertight Appliances.

Appliances of the non-watertight types are of commercial varieties, and replace the more expensive watertight types in locations outside of the watertight system of the ship, especially in those locations which are occupied as quarters, offices, etc. Non-watertight appliances should never be used in locations which will be washed down with hose.

FIG. 57.—5-ampere switch, N. W. T.

FIG. 58.—N. W. T. key receptacle.

5-Ampere Switch.—The switch is the single-pole, snap switch shown in Fig. 57.

The circular porcelain base has two raised bosses to which are held small brass connectors by screws through the base; the connectors are fitted with contact screws to which the leading wires can be directly connected, or they can be led through holes in the base. The copper fingers are riveted to the connectors and make contact on a switch barrel similar to the method of the 5-ampere watertight switch. The barrel contacts are held by a solder joint, run into a recess in two opposite ratchet teeth, and are connected together through the barrel. The switch stem is flared under the base and held by a slotted brass washer; it is secured to the barrel by a coiled spring, one end of which goes over a pin on the stem and the other takes in the interior recess of the barrel. The switch handle screws on and is held by a set screw.

The cover is of spun brass, lined with asbestos, dome-shaped, and finished in bronze; it is held in place by the switch handle and is kept from turning by a notch on the lower edge which fits over a lug in the porcelain base.

The switch is commercially rated at 10 amperes.

The direction of turning is to the right and no device except the resistance of the switch fingers prevents turning in the wrong direction.

The appliance is secured through screw holes in the base; when installed in connection with conduit work it is attached to a terminal box similar to that shown in Fig. 56 and the wires are led through the two holes in the base.

10-Ampere Switch.—The essential feature is that the switch is double-pole; this is important and has been much overlooked, causing errors in installation and contract deliveries. The base is the same as for the 5-ampere, except that the bosses are higher and there are four holes for the wires instead of two. Similar short connectors are used with the same construction of finger; four fingers are used, two in each pole, one of each pair being secured to the upper surface of the base and one to the boss. The barrel is similar to that of the 25-ampere watertight switch, the contact plates being secured by solder as in the non-watertight 5-ampere switch, and connected through the barrel. The stem construction, method of holding to the base, handle and cover fastening are the same as for the 5-ampere non-watertight, but the cover is higher to accommodate the extra height for the fingers and is lined with asbestos.

The switch turns to the right and has no device except the resistance of the switch fingers to prevent turning in the wrong direction.

The appliance is secured through two screw holes in the base; when installed in connection with conduit work it is attached to a terminal box similar to that shown in Fig. 56 and the wires are led through the four holes in the base.

Receptacles.

Key Receptacles.—The appliance is shown in Fig. 58.

The porcelain has a flat circular base with a central porcelain column. To the column is first screwed a D-shaped piece of brass in whose upright ends the key spindle journals. At the

key end this stamping is branched for a contact screw for one fuse; at the opposite end the journal is deepened to allow for the spring action. The key stem has a through pin or plate inside each side of the D-shaped piece to keep those sides in place, and on the opposite end from the handle and inside the D is a rectangular piece of brass which, when vertical, electrically connects the shell of the socket with the switch stem; the piece of brass works against a phosphor bronze spring plate to give a snap action.

The other electrical terminal is a tongue of brass ending in a plate against which the center of the lamp base, or attachment plug, rests, and to which the center connects electrically. The tongue is bent down and screwed to the column and is tapped in for the second fuse. The socket shell is cut away, where the tongue passes through, to give large room to prevent short circuit.

The socket shell is of spun brass, threaded to take the Edison base of the lamp or attachment plug; it is inwardly flanged at the bottom and held to the column by two screws.

The tongue is often bent down when a lamp or plug is screwed in hard and, to prevent short-circuiting, a disc of mica is laid under the tongue.

The wire contacts are two brass plates held by screws to the flat base. Each contact has two contact screws, one for the wire lead, the other for a piece of fuse wire to fuse the gap between the wire contact and the contact screw of the tongue in one pole, and that between the wire contact and the contact of the D-shaped journal of the switch stem in the other pole. The fuse is no longer used in naval work; the gap is bridged with a metal connector.

The cover is of spun brass with an aperture large enough to fit over the switch handle. A broad notch at the bottom, and directly below the handle aperture, fits over a corresponding elevation on the base and prevents the cover from turning. The cover is held in place by an insulating ring of hard rubber, whose internal thread fits the thread of the socket. The cover is lined with asbestos.

The receptacle is secured by two screws; when installed in connection with conduit it is attached to a terminal box, similar to that shown in Fig. 56, the difference being in the shape and arrangement of parts.

Keyless Receptacle.—This appliance, shown in Fig. 59, differs mainly from the key receptacle in the omission of the key construction; the column is not so high and has a one-sixteenth inch raised projection against which a broad tongue is held in the bend on the side by the fuse screw; the socket shell is held by two screws, and by a horseshoe-shaped connector which has a tongue and contact screw for the fuse in the other pole; the cover is lower and has no device to prevent turning. The wire contacts, fusing, and other details are similar to those of the key receptacle.

The keyless receptacle is installed when the local use ot a key is not necessary.

The double receptacle (Fig. 51) now replaces both the key and keyless receptacles.

FIG. 59.—N. W. T. keyless receptacle.

FIG. 60.—Standard key socket.

Lamp Sockets.

These appliances are the receptacles for securing and supplying the incandescent lamps in the various types of fixtures and instruments.

Key Socket (Fig. 60).—There are two parts, an interior fitting and a shell.

The function of the interior fitting corresponds in most details with the column parts of the N. W. T. key receptacle. It is not fused and there are no lower contacts as in the key receptacle; the key construction is the same in both. A commercial spun socket shell is secured to the porcelain by two screws and is cut off at the height of two threads, the remaining threads being replaced by a coiled spring of No. 11 phosphor bronze wire, of seven turns, of which three-quarters of a turn are soldered in the thread of the spun shell and 6¼ turns are free in the spring; the outer end of the spring is turned back in a

loop, *to be pressed back and loosen the spring when unscrewing the lamp*. The threads of the lamp base run in on the spring as on the thread of the socket shell of the key receptacle; the object of the spring device is to protect the lamp from loosening or breaking from the effect of shock or vibration.

The shell is in two parts, a top and a base. The top is of spun brass; it has one slot at the bottom to slip over the key stem, and two slots to slip over the retaining screws which hold it to the base by the pressure of the screw heads; the ends of these screws enter a recess in the porcelain and hold the interior fitting in place. The upper part of the base is of spun brass, reinforced inside by two spring straps, double the thickness of the brass spinning, to afford a bearing for the screws which assemble the side.

FIG. 61.—Standard keyless socket.

FIG. 62.—Type A socket.

The bottom of the base is a casting tapped for the pipe thread of the pipe of the fixture to which it is to be attached, a slotted head set screw preventing turning.

The wiring is led through the pipe and base to attach to the contact screws of the interior fitting. The shell is finished in dark bronze in consonance with the finish of the fixture with which the socket is to be assembled.

The side of the shell is insulated from the coiled spring by a ring of hard rubber, bent to shape and slipped in at the top between the shell and spring.

Keyless Socket.—The porcelain block for the interior fitting of the keyless socket (Fig. 61) differs from that of the key socket in the omission of key parts. The coiled spring and tongue connection are the same. As in the keyless receptacle, a horseshoe-shaped piece of brass is assembled with the inside flange of the bottom of the spun socket (to which the contact for one pole is attached). The side of the shell omits the slot

for the key, but is otherwise the same as for the key socket and assembled in the same way. The shell is finished in dark bronze.

Type A Socket, or Porcelain Base Receptacle.—This type of socket shown in Fig. 62, is now replacing the key and keyless sockets in many constructions (especially fixtures) as it is cheaper, has better insulation and is more readily wired up; the difficulty of leading in through the bottom of the base of the other two sockets, and attendant delay and cost is also eliminated. It has no cover or shell and consists essentially of the mountings of a keyless socket on a special porcelain base. The efficiency of circuit insulation in conduit installations is largely due to the use of this socket.

FIG. 63.—Candelabra base, or instrument lamp socket.

FIG. 64.—Push button, N. W. T.

The base is secured by a through No. 8 machine screw on one side, and on the other by a machine screw of the same size, which sets against a shoulder in a slot, permitting the taking up of a variation of one-quarter of an inch in centers.

A deep groove for the entering wires runs across the bottom of the base. The porcelain is so struck on the top of the base as to form a shoulder for leading the wires to contacts whose center line is 90 degrees from that of the bottom groove and in the same vertical plane as the securing screws. All screw holes for screws securing the mountings are countersunk and filled with a water-excluding material.

Instrument Lamp Socket.—This socket (Fig. 63) takes the 5-candle power instrument lamp base. The porcelain is held by screws at diagonally opposite corners.

The copper spinning and spring are constructed like the similar parts of larger sockets. One connector is soldered to the copper spinning; the other dips down into a recess of the porcelain, and extends up vertically into the socket center, where it is secured by a copper screw over an insulating disc of mica. The same screw acts as a wire contact and for securing the connector.

Push Buttons.

Push buttons are a simple variety of through-connection or switch for low-voltage lines, such as for bells and buzzers.

There are two types of push buttons: A flat type, known as Watertight and Non-watertight Push Buttons, to be installed against surfaces on lines of bell wiring; a pear-shaped type, known as Single, Double, and Triple Pear Push Buttons, designed to be attached to loose bell cords, to hang over tables, beside desks, etc.

Non-watertight Push Button.—The appliance, shown in Fig. 64, is a brass casting and consists of four parts, a base, a cover, an interior fitting, and a push.

The base casting is hollowed out in the center for lightness and for a direct lead for the wiring; it has a cast collar, threaded on the outside, to which the cover screws. In a recess of the collar is placed the interior fitting. The cover is a casting, threaded on its inner, lower edge to take on the threaded collar of the base, and perforated at the top for the push.

The interior fitting is a disc of hard rubber, perforated for two screws which hold the complete push button in place, and two smaller holes, through which the wires are led to the contact springs. There are two German silver contact springs; one, laid flat, and half-moon in shape to bring the inner end to the center of the hard rubber disc and at the same time clear the other connector, is secured to the disc by a screw, a second screw with small brass washer forming the wire contact; the second connector is bent into a spiral and is secured to the disc by a screw, the wire contact being the same as for the first connector, this connector is sprung off the disc to give a clearance of about ⅛ inch between its inner end and that of the first connector. The inner ends of each connector are fitted with a small pin rivet of platinum to decrease the effect of sparking, and insure a clean, bright contact.

A notch in the side of the hard rubber fits a lug in the base and secures the fitting against turning.

The push is a piece of hard rubber about 7/16 inch in diameter at the top, with a small flange at the bottom about ⅛ inch larger in diameter, which presses on the spiral connector inside the button, and brings the platinum points of the connectors

into contact. In conduit wiring the button is attached to a terminal box similar to Fig. 56.

Watertight Push Button.—The watertight push button is similar in construction to the non-watertight, but the base is made solid excepting for a perforation on one side about ½ inch in diameter, in which fits a hard rubber plug with two holes for the leading-in wires.

The construction of the interior fitting is similar to that for the non-watertight button. The cover is the same excepting, first, at the top is a collar with an outside thread, to which is fitted an inside-threaded ring holding in place a lace leather disc

FIG. 65.—Parts of single pear push button.

which covers the push of the button and watertights the top; second, a watertight packing is placed under the cover. The lace leather is more serviceable than rubber, preserving its flexibility when exposed to salt water and not softening when acted upon by oil. In conduit wiring the button is attached to a terminal box similar to Fig. 56.

Single Pear Push Button.—The single type is installed when but one station is to be called. Fig. 65 shows the type of appliance. It consists of hard rubber turned in two sections, a base. and a cover; the cover is threaded to take an inside thread in the recess of the base.

The lower part of the base is drilled to take a double bell cord, and holes are drilled through to the base recess through which the bell cord can be drawn (after stripping the silk braid) and the wires branched out to the two contact screws, with washers,

within. In the center of the recess is bored a hole about ¼ inch deep, in which is set a spring which embraces the pin of the contact disc.

The contact disc is made of German silver, and has a small central pin to take the spring. This contact disc when pushed down on the two contact screws to which the wires are fastened completes the circuit between the two wires of the bell cord. A nickeled brass push is inserted through the hole in the cover to take on the contact plate; the push is kept in place by the cover; the contact disc is kept off the contact screws by the spring.

Double Pear Push Button.—This type is installed when two stations are to be called from one appliance.

The double pear push button is similar in appearance to the single pear push though slightly larger and has two pushes, one at the end and one on the side. The base is bored out leaving a wall thickness of about ¼ inch which is inside-threaded at the top to take the thread of the cover. Inside the base fits a hard rubber plug carrying the contact screws. The plug is planed off on one side for the connections for the side push, and holes are drilled through for the wires (without silk braid) of the triple bell cord. The battery wire contact screws for the top and side push are connected together by a brass strip.

The two contact discs, springs, and pushes are the same as for the single pear.

Triple Pear Push Buttons.—This type admits of calling three stations from one appliance.

The triple pear push is of the same size as the double pear and has two side pushes in addition to the end push.

The only essential difference is in the plug which is planed away on two sides for two side constructions similar to the side construction of the double pear push button.

The three-battery wire-contact screws are connected together by a strip of brass.

There being no standard bell cord, quadruple, the conductor is laid up by hand from single silk conductors.

Ceiling Button.—This is a small circular porcelain appliance used as a finish at the upper ends of bell cords, and is secured by two screws. The base of the ceiling button is hollowed out, and scored on opposite sides, for the lead of the bell wires, which are to be connected to the bell cord. In conduit wiring it is replaced

by a hard rubber bush in the cover of a terminal box similar to that used for the non-watertight push button.

Auxiliary Wiring Appliances

Gaskets—The term gasket is generally restricted in electrical installations to the eight types of soft rubber appliances for water-tighting, of the shape of two truncated cones of unequal heights joined base to base, and resembling rubber corks; these are perforated to fit over the wires or conduits, and are set up by a gland and washer. Gaskets are generally molded from a rubber composition which is required to be as follows:

FIG 66.—Types of gaskets.

To be made of a vulcanized rubber compound which shall contain nothing but pure Para rubber gum, of the best grade, mixed with dry mineral matter and sulphur only. The compound to contain at least 60 per cent, by weight, of rubber gum, and the weight of sulphur not to be less than 4½ per cent nor more than 5½ per cent of the weight of the rubber gum in the compound This sulphur shall all be combined with the rubber so that there shall not be more than two-tenths of one per cent of free sulphur in the compound.

After vulcanization and manufacture into gaskets, the character of the compound to be such that when a test piece having a section of about 0.03 square inch is placed in jaws 2 inches apart, or as nearly 2 inches as may be practicable, and the jaws sepa-

rated at the rate of 3 inches per minute, subjecting the rubber to a tensile test, to be capable of being stretched to five times its original length, without rupture and not break under a tensile stress of less than 750 pounds per square inch.

When subjected to a tensile stress of 600 pounds per square inch continuously for ten minutes the compound to be of such a character as to return to within 15 per cent of its original length at the end of ten minutes after being released.

The specific gravity of the compound not to be less than 1.3.

The several types of gaskets are designated by a type letter in accordance with the outside dimensions of the gasket (Fig. 66). Varieties of the same type are designated by a number, generally separated from the title letter by a dash, which conveniently designates the diameter of the perforation in the gasket in thirty-seconds of an inch; for instance, A-14, B-20, D-13, indicate a gasket of A, B, or D, sizes in which the diameter of the hole is 14, 20, and 13 thirty-seconds of an inch, respectively.

If the type letter is a single letter, as A-14, it indicates that there is but one perforation in the gasket; if there are two perforations for the same size the gasket is called AA-14, etc.

When a gasket is represented as A-0, B-0, etc., it indicates that the gasket has no perforation and is solid; such a gasket is used for plugging up or blanking off, but the occasion is rare except with appliances for molding.

Gaskets which are designated by two numbers, as A-24-13, are for packing twin conductor, and have a single perforation with semicircular ends of which the first number, 24 in the example above, is the length of the perforation and is one thirty-second of an inch larger than the major axis of the twin wire; the second number, 13 in the example above, is the width of the perforation and is one thirty-second of an inch smaller than the minor axis of the twin wire.

Attachment Plugs.

Attachment plugs are appliances which are used on the ends of wire for plugging into receptacles, switch and receptacles and the like, and form the electrical connections to the permanent ship wiring of the particular fixture or apparatus to which they are wired.

5-Ampere Watertight Attachment Plugs.—This appliance, shown in Figs. 50 and 51, consists, first, of a hard rubber plug having a threaded collar at the top by which it secures in the assembly. On the sides of the plug are two copper connecting plates held by two brass screws, each having a contact screw under which one of the wires (usually from a double conductor, plain) are secured. The plates are insulated from each other by the substance of the plug, *and the plug is therefore double pole when inserted in the clips of the receptacle.*

The brass parts consist of a collar turning in a ring which is inside-threaded to take the tube of the box appliance, the recess being packed with a ring washer of sheet rubber packing to prevent access of water. The collar is knurled on the outside. The upper part of the brass tubing, into which the hard rubber plug is screwed, is reamed for packing with a D-13 gasket, and the gasket is held in place by a gland, working against a brass washer. The two wires of the double conductor, plain, are bared to the vulcanized rubber layer, and led down through holes in the hard rubber plug to connect to the contact screws.

This appliance has the great disadvantage that the screw collar at the top of the hard rubber plug has insufficient strength and is easily broken. A newer type of this appliance uses lignum vitæ boiled in paraffin instead of hard rubber. This type of plug is watertighted better at the leading-in wires than the type explained above; the breakage proves to be lessened only to a small degree.

25-Ampere Watertight Attachment Plug.—This type is to be inserted into a receptacle *which is single pole instead of double pole, the clips of the 25-ampere receptacle, or switch and receptacle, being connected across by the plug contacts from one to the other. The plug differs from the 5-ampere plug in having the contact plates connected across the plug end,* thus making it a single pole; the two leading-in wires attach to the contacts of either side.

Non-Watertight Attachment Plug.—This plug is shown in Fig. 67. It consists of a piece of hard rubber, recessed at the top for a depth of half an inch, and having a central hole dropping from the recess for a distance of ¼ inch. A screw enters this smaller recess from the bottom and secures a brass connector which is bent up into the larger recess and ends in a con-

tact screw for one wire, the screw completing the connection. On the outside of the plug is threaded a brass spinning which is connected through by a soldered wire to a contact on the inside. From this contact a fuse wire connects to a similar contact, placed at a distance of about ½ inch on the inside circumference of the recess, to which the second wire for the connection is secured. The commercial attachment plug is therefore fused; this is not necessary, one contact is now omitted, for naval use, and the fuse gap bridged.

The upper part of the plug is threaded on the outside for a brass cap, finished in bronze, which holds a hard rubber disc, covering the inside recess of the plug. The hard rubber disc and the cap are perforated to admit the conductors.

The appliance is used on the ends of wiring (usually double conductor, silk) for fans, desk lights, etc., but is now being replaced by the 5-ampere watertight plug by reason of the installation of double receptacles instead of non-watertight appliances.

FIG. 67.—N. W. T. attachment plug.

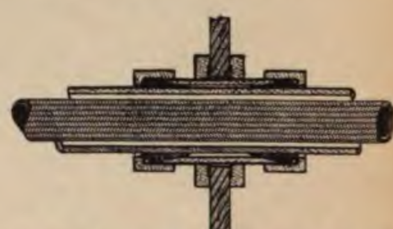


FIG. 68.—Cross-section of conduit tube through a bulkhead.

Stuffing Tubes.

The requirements of watertighting the fitting of various parts of conduit lines has given rise to a line of stuffing tubes differing for the particulars for which they are applied.

Conduit Tube.—The tube, shown in section in Fig. 68, is employed for watertighting *conduit* when run through decks or bulkheads. It is of drawn tubing and beveled inside the ends for the gasket; it is threaded for its whole outside length if the tube is to be short, otherwise an unthreaded portion is left in the central part of the tube and the ends are threaded for the necessary length for nut and gland; the length of the tube will differ with the thickness of the metal and wood through which it is to

CONDUIT STUFFING TUBES.

Nominal size.	Clearance hole in bulkhead.	Tube. Seamless brass tubing, threaded entire length, 18 threads per inch.					Gland.				Washer.				Nut.			Gasket.
		Outside diameter.	Inside diameter.	B. & S. G.	Length. For $\frac{1}{2}$-inch bulkhead.	Length. For 3-inch deck.	Outside diameter.	Length.	Inside diameter at flange.	Thickness of flange.	Outside diameter.	Inside diameter.	Thickness.	B. & S. G. of tubing.	Over corners.	Over flats.	Thickness.	Type.
$\frac{1}{2}$	$1\frac{5}{16}$	$1\frac{1}{4}$	$\frac{7}{8}$	No. 5	$2\frac{1}{4}$	......	$1\frac{1}{2}$	$\frac{9}{16}$	$\frac{7}{8}$	$\frac{3}{16}$	$1\frac{1}{8}$	$\frac{7}{8}$	$\frac{3}{64}$	No 8	$2\frac{1}{16}$	$1\frac{3}{4}$	$\frac{1}{4}$	B. 27
$\frac{3}{4}$	$1\frac{9}{16}$	$1\frac{1}{2}$	$1\frac{3}{16}$	No. 6	$2\frac{3}{4}$	$5\frac{1}{4}$	$1\frac{3}{4}$	$\frac{3}{4}$	$1\frac{3}{16}$	$\frac{3}{16}$	$1\frac{5}{8}$	$1\frac{3}{16}$	$\frac{3}{64}$	......	$2\frac{7}{8}$	$2\frac{1}{2}$	$\frac{5}{16}$	A. 34
1	$1\frac{13}{16}$	$1\frac{3}{4}$	$1\frac{3}{8}$	No. 5	$2\frac{3}{4}$	$5\frac{1}{2}$	$2\frac{1}{8}$	$\frac{3}{4}$	$1\frac{3}{8}$	$\frac{4}{16}$	$1\frac{5}{8}$	$1\frac{3}{8}$	$\frac{3}{64}$	No. 8	$3\frac{3}{16}$	$2\frac{3}{4}$	$\frac{3}{8}$	F. 42
$1\frac{1}{4}$	$2\frac{5}{16}$	$2\frac{1}{4}$	$1\frac{7}{8}$	No. 5	$3\frac{1}{2}$	6	$2\frac{5}{8}$	1	$1\frac{7}{8}$	$\frac{3}{16}$	$2\frac{1}{8}$	$1\frac{7}{8}$	$\frac{3}{64}$	No. 8	$3\frac{7}{8}$	$3\frac{3}{8}$	$\frac{3}{8}$	G. 54
$1\frac{1}{2}$	$2\frac{9}{16}$	$2\frac{1}{2}$	2	......	4	$6\frac{1}{2}$	$2\frac{7}{8}$	$1\frac{3}{16}$	2	$\frac{3}{16}$	$2\frac{3}{8}$	2	$\frac{3}{64}$	......	$4\frac{5}{16}$	$3\frac{3}{4}$	$\frac{7}{16}$	J. 61

be run. On the thread run two hexagonal nuts which clamp the tube to the bulkhead or deck. The recess in the nuts is packed with lamp wick and red lead to prevent a flow of water between the nuts and the metal to which the tube is secured. The gaskets are set up by glands running on the outside threads.

When conduit is run through armor a tube is not necessary, other methods of water-tighting being used.

Bulkhead Tube.—The bulkhead tube is a conduit tube *having but one end fitted for gland, washer, and gasket.* The jam nuts have a score instead of a recess which is to be filled with red lead to watertight between the nut and the ship metal.

The bulkhead tube accomplishes the ordinary demands of installation, the conduit tube being for locations where the conduit must be packed on both sides; it is better to use the recessed nut of the conduit tube than the scored nut of the bulkhead tube as lamp wick and red lead make a better joint than red lead alone.

If the bulkhead tube is to be short it is outside-threaded for its whole length, otherwise an unthreaded section is left in the center. It will answer for a deck tube as well.

Box Tube.—The box tube is a small, short bulkhead tube having no jam nuts, and, is used for stuffing wires entering fixtures, and similar uses which require a short tube only.

Watertight Box Tubes.—The modifications of the conduit and bulkhead tubes for this use are illustrated in Fig. 69, showing the arrangement when the watertight box can be located near the bulkhead—the more advisable—and also when such arrangement is not practicable.

Terminal Tube.—The terminal tube is worked on the end of a conduit line when necessary to watertight wiring which is to be run open to cleats, insulators, etc.

When the conduit is to end at a bulkhead the watertight box tube is used as a terminal tube, but modified as follows: The shank of the tube (the part threaded with a pipe thread) is threaded to the shoulder instead of only part way; this shank is made long enough to pass through the bulkhead, take a nut (with red-lead groove) on each side of the bulkhead, and take its half of the coupling joining it to the conduit. One of these nuts is set up tight against the shoulder of the tube; watertightness is secured by setting up on the nut on the other side of the bulkhead.

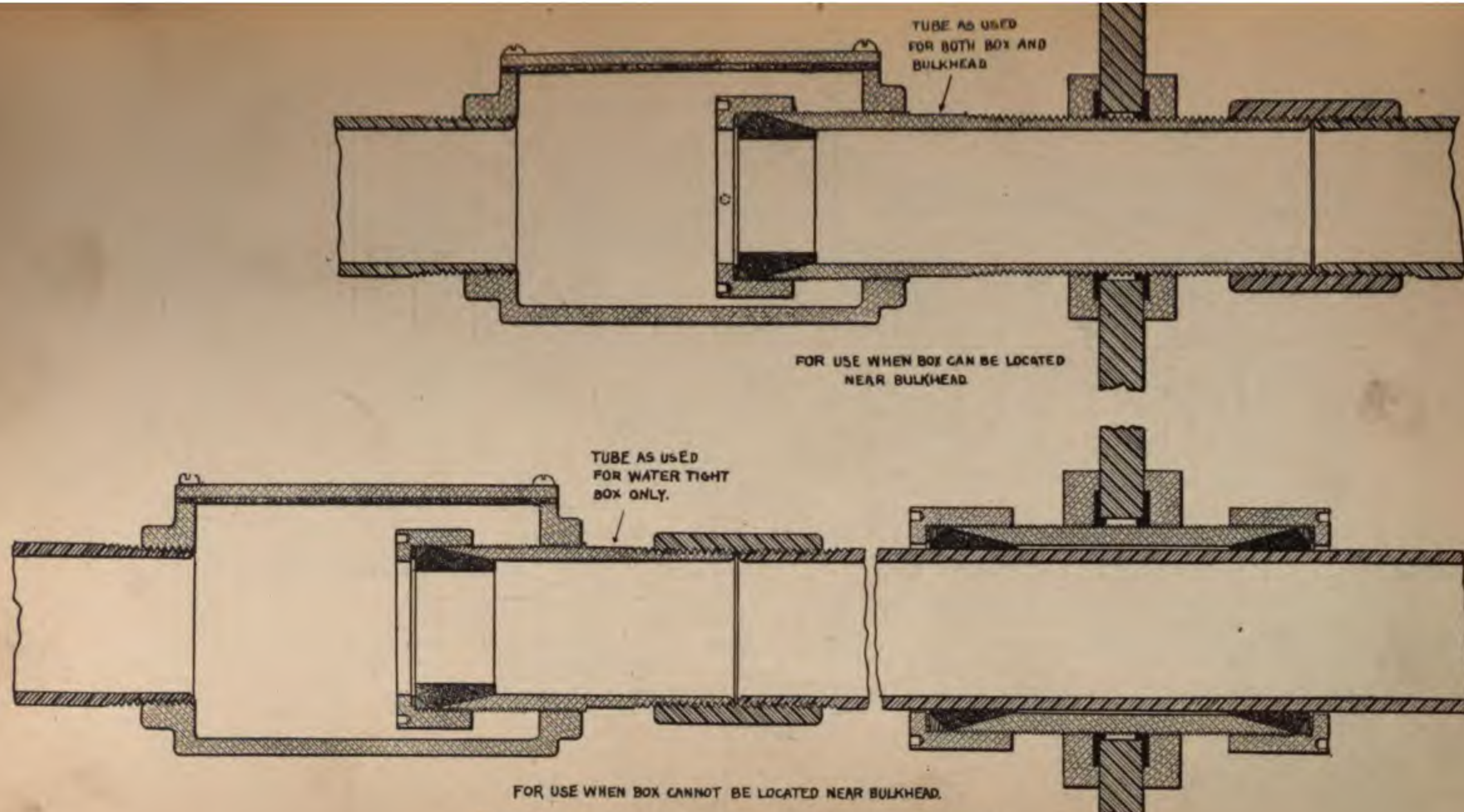


Fig. 69.—Watertight box tubes and watertight boxes.

BULKHEAD STUFFING TUBES AND BOX TUBES.

Nominal size.	Clearance hole in bulkhead.	Tube. Seamless brass tubing, threaded entire length, 18 threads per inch. Iron-pipe size.	Tube. Seamless brass tubing. Diameter of thread.	Tube. Seamless brass tubing. Inside diameter.	Tube. Seamless brass tubing. Length. Bulkhead.	Tube. Seamless brass tubing. Length. Box.	Tube. Hard-rubber lining, 1/8 inch longer than tube. Outside Diameter.	Tube. Hard-rubber lining. Inside diameter.	Tube. Outside diameter.	Gland. Length.	Gland. Inside diameter at flange.	Gland. Thickness of flange.	Washer. Outside diameter.	Washer. Inside diameter.	Washer. Thickness.	Washer. B. & S. G. of tubing.	Nut. Over corners.	Nut. Over flats.	Nut. Thickness.	Gasket. Type.	Gasket. Maximum hole in 32ds of inch.
7/16	7/8	1/2	13/16	0.62	1 11/16	1 1/16	5/8	7/16	1	9/16	19/32	3/16	23/32	9/16	3/64	No. 12	1 3/4	1 1/2	5/16	D.	14
5/8	1 1/8	3/4	1 1/16	0.82	1 11/16	1 1/16	13/16	5/8	1 1/4	9/16	13/16	3/16	31/32	25/32	3/64	11	2 1/16	1 3/4	5/16	C.	20
13/16	1 3/8	1	1 5/16	1.04	2	1 1/4	1 1/16	13/16	1 1/2	5/8	1 1/16	3/16	1 3/16	15/16	3/64	8	2 5/16	2	3/8	B.	26
1 1/8	1 11/16	1 1/4	1 5/8	1.38	2 1/8	1 3/8	1 3/8	1 1/8	1 7/8	3/4	1 3/8	3/16	1 9/16	1 5/16	3/64	8	2 3/4	2 3/8	5/8	A	36
1 5/16	1 13/16	1 1/2	1 7/8	1.61	2 1/4	1 1/2	1 5/8	1 5/16	2 1/8	7/8	1 9/16	3/16	1 3/4	1 1/2	3/64	8	3 3/16	2 3/4	5/8	F.	42

TUBES FOR WATERTIGHT BOXES AND CONDUIT TERMINAL TUBES.

Nominal size.	Clearance hole in bulkhead.	Dimensions of all tubing.					Tube for water-tight box.			Terminal tube.		Gland.			Washer, 3/32 inch thick.			Nut.			Gasket.	
		Gland end.			Conduit end.		Total length.															
		Outside diameter.	Inside diameter.	B. & S. G.	Outside diameter.	Inside diameter.	Box only.	Box and bulkhead.	Length of gland end, 18 threads per inch.	Total length.	Length of gland end.	Outside diameter.	Length.	Inside diameter at flange. Flange 3/16 inch thick.	Inside diameter.	Outside diameter.	B. & S. G. of tubing.	Over corners.	Over flats.	Thickness.	Type.	Maximum hole in 32ds of inch.
			In.	*No.*	*In.*												*No.*					
1/2	1 1/16	1	0.60	4	0.84	.....	3	6	1 3/8	3	9/16	1 1/4	9/16	3/4	3/4	29/32	11	1 3/4	1 1/2	1/4	C.	20
3/4	1 5/16	1 1/4	0.80	3	1.05	.....	3	6	1 3/8	3	9/16	1 1/2	9/16	7/8	15/16	1 1/8	11	2 1/16	1 3/4	1/4	B.	26
1	1 9/16	1 1/2	1.04	3	1.31	.....	3 1/2	6 1/2	1 7/16	3 1/2	3/4	1 3/4	3/4	1 3/16	1 3/16	1 3/8	11	2 5/16	2	5/16	A.	36
1 1/4	1 13/16	1 3/4	1.39	5	1.66	.....	3 1/2	6 1/2	1 7/16	3 1/2	3/4	2 1/8	3/4	1 3/8	1 3/8	1 5/8	8	2 3/4	2 3/8	3/8	F.	42
1 1/2	2 1/16	2	1.60	4	1.90	.....	3 5/8	6 5/8	1 9/16	3 5/8	7/8	2 3/8	7/8	1 5/8	1 5/8	1 7/8	8	2 13/16	2 3/4	3/8	K.	50

The enlarged part of the tube may be shortened to a length equal to that of the gland, or made longer if more advantageous.

A recessed nut is preferable to one with read-lead groove.

When the conduit ends flying, as in a berthing space, a short bulkhead tube is used for packing the terminal, screwing into a coupling. In similar cases when it is not necessary to pack the terminal, the type of terminal known as the T. & B. Bush or outlet insulator is used; its advantage is that the smooth, rounded, exterior edges will not abrade or injure the naked wire like the sharper edge of conduit pipe, however carefully the conduit may be finished off. The type is of cast iron and is commercial.

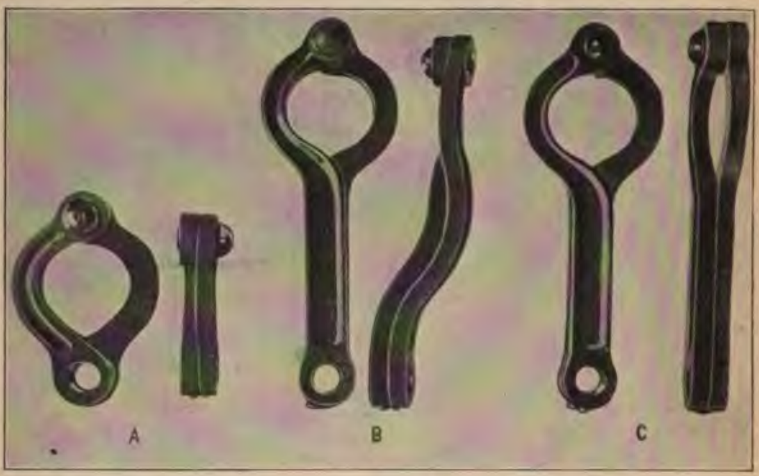


FIG. 70.—Hinged hangers.

Hard-rubber Bushes.—When wire or cable (without duct) is run through a bulkhead, etc., and watertightness is not necessary, such wire or cable is insulated at the bulkhead by bushes of hard rubber cut from hard-rubber tubing. To prevent the bushes from working out of place they are secured in as follows:

The tubing is cut about one inch longer than necessary for the aperture, and each end is softened in hot water. The bush is then put in place and a conical piece of metal placed in each end; the pieces of metal are connected by a through bolt and, as the nut is set up, the bush ends are flared, holding the bush securely in place when the ends have cooled and hardened. Straight bushes cut from tubing are used to bush all holes in beams, etc., through which wires are led in molding work.

Conduit Hangers.—Three types are shown in Fig. 70. *A* is the type for angle irons or against a surface having no offset; *B* is the type for double bulb beams, similar to *C* but having a curve in the shank to fit the bulb; *C* is a type adapted for channel beams or the flat side of a single bulb beam. The two pieces are of malleable iron and hinged below the swell for the conduit. After slipping over the conduit the drilled ends are brought to-

FIG. 71.—Hanger for channel beams.

gether and a ⅜-inch bolt put through both hanger ends and the beam or angle; a nut secures all in place.

The foregoing necessitates the objectionable practice of drilling the beam. Fig. 71 shows a type of clamp requiring no drilling or tapping of beams, but is adapted for channel beams only; it can be used for pipes of larger size than conduit. The clamp is

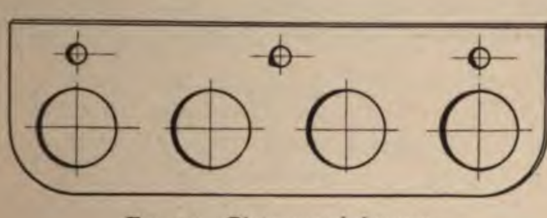


FIG. 72.—Plate metal hanger.

of malleable iron in one piece and draws the conduit securely against the beam by two case-hardened, square-headed set screws.

The type of hanger very generally used in contract-built ships is shown in sketch in Fig. 72.

It is of sheet iron or sheet steel, sometimes thin plate, which is punched or drilled to take conduit of the required size; it is secured by hexagonal-headed bolts through the beam and set up

with nuts. For bulb beams, etc., the plate is bent; an angle iron is attached for use against decks or bulkheads.

It has the advantage of being simple and comparatively cheap and of light weight; its disadvantages reside in having to take down a number of conduits when only one circuit is to be overhauled, and its inconvenience of installation near bends in the conduit. When this type of hanger is installed the number of conduits in any one hanger should be restricted to that which will insure a small amount of labor in handling the conduits for repair work.

Conduit Straps.—Conduit straps (Fig. 73), are for securing conduit when run along flat surfaces and are made of the same material as the conduit which they secure.

FIG. 73.—Conduit straps.

There are two types, a light, known as A and C, and a heavy, known as B and D. The light straps are made of No. 16 U. S. S. G. sheet iron, or No. 14 B. & S. G. sheet brass; they are used in quarters, etc., where the conduit is not likely to receive mechanical stresses. The heavy straps are used elsewhere and are made of 3/16-inch iron or brass.

The light types are secured with a 5/16-inch button-head cap screws, the heavy with ⅜-inch iron, hexagonal tap bolts.

Lock Nut.—Single lock nuts, as distinct from the jam nuts for stuffing tubes, are occasionally required for following up a coupling to its place on a joint. They are of cast iron and of commercial pattern.

Cleats.—Porcelain cleats (*A*, Fig. 74) are sometimes used in non-watertight wiring instead of insulators for securing wiring in place. They are of commercial porcelain types in a variety of sizes, and are secured by machine or wood screws as necessary. The cleat is usually reinforced by a metal cap or plate, to hold the pieces of porcelain temporarily in case of breakage or fracture.

Hooks.—Three types in general use are shown in Fig. 74.

B is a type derived from the post of the upper part of the desk light fixture and intended to be placed in convenient places

about staterooms, etc., for hanging the lamp carrier when taken off the base stand.

C is a type for suspending the bight of bell cords and the desk light wires; the hook part is covered by a rubber sleeve for insulation and to prevent chafe.

D is the ordinary commercial 1½-inch cup hook, for the same purpose as *C*, but for securing in wood only.

Fuses.

A fuse is an appliance which is inserted in an electrical circuit to protect that circuit from a current of such a magnitude as

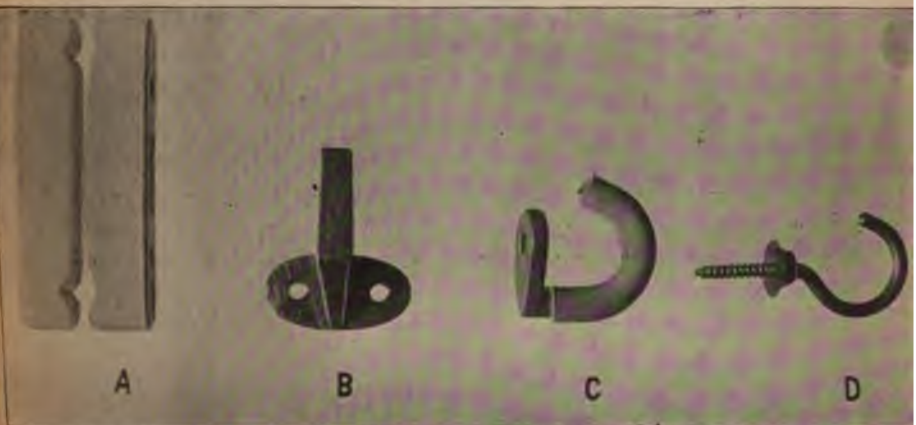


FIG. 74.—Cleats and hooks.

would overheat and injure the apparatus or the insulation of the wire; the fuse melts and breaks the circuit. Fuse material may be of any metal or alloy; the restricting conditions are, that the material shall melt under the heat generated in the conductor when the maximum permissible current passes, and that the fuse shall be sufficiently substantial to permit ordinary usage in handling, though not to be too bulky. Pure copper has certain advantages, but is not available, the principal objection being that the high temperature of the fused metal introduces a risk from fire.

The determination of fuse dimensions and material is based upon equating the amount of heat generated in the fuse, at the

temperature of fusion, with the heat radiated from the surface under the same conditions; the equation eliminates length of fuse and time, but in practice it is found that the length should be many times the diameter to compensate for the cooling effect of the clamps or terminals to which the fuse is attached. The practical determination of proportions for the alloy for fuses for naval use is determined by standards of temperatures of fusion, Fahrenheit, as follows: (Manufacturers differ in variations of mixture and proportion):

Melting Point.	Lead.	Tin.	Bismuth.
210°	5	3	8
246°	1	4	5
286°	..	1	1
334°	..	2	1
334°	2	3	..

The character of the alloy is specified to be such that there will be no reddening or excessive elongation when the current is slowly raised until the temperature of fusion is reached, and the maximum current is to be double that of the rated carrying capacity of the fuse, that is, a fuse rated at 20 amperes should not "blow" below 40 amperes. All fuses should carry 50 per cent of current above their rated capacity without being affected. The carrying capacity, or maximum permissible amperage, is determined by cross sectional area for a given alloy; when the cross section is circular the diameter is taken as the measure of cross-section.

Dynamo Fuse. (Fig. 75, A).—It is inserted to bridge the gap between the switchboard terminals for the dynamo leads and the terminals to which the bus bar connections are made; if a circuit breaker is installed at the switchboard end of the dynamo leads, a fuse is unnecessary, but if the circuit breaker is mounted on the dynamo headboard a fuse is properly inserted on each leg at the switchboard. Dynamo fuses are copper tipped and designed to mount on ⅜-inch bolts, with 2⅛-inch distance between centers; the copper tips are proportioned in thickness to the capacity of the fuse. The standard rated capacities are 25, 50, 75, 100, 200, 300, 400, and 500 amperes. The rated capacity is stamped on one of the lugs. Dynamo fuses made entirely of zinc have proved satisfactory.

Switchboard Circuit Fuses.—This type is employed to fuse the gap between the circuits on the switchboard and the bus bars.

The type for the former 1892 standard switchboard, and known as the push-clip fuse, is shown in Fig. 75, *B* and *C*, which differ from each other mainly in the thickness of the copper clip. The type used with the present standard switchboard is shown in Fig. 75, *D*. They are of the commercial copper-tipped pattern, designed to mount on No. 10 screw studs, with 1 11/16 inches between centers. The slots in the tips are at right angles. The material is either fuse wire or fuse strip. The rated capacity

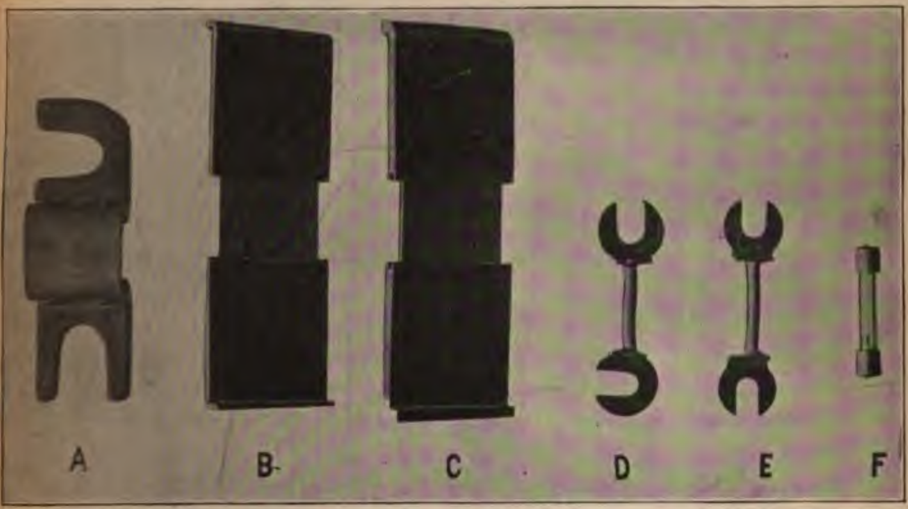


FIG. 75.—Types of fuses.

is stamped on one of the tips. The actual length of fuse metal must be at least one inch.

The different rated capacities of switchboard fuses are 10, 15, 20, 30, 40, 50, 60, 75, and 100 amperes; when a fuse of greater capacity than 100 amperes is required, as for a motor circuit, a dynamo fuse is employed.

Feeder Box Fuses.—Fuses for feeder boxes (Fig. 75, *E*) are of commercial copper-tipped pattern, designed to mount on No. 8 screws with 1 9/32 inches between centers. The tip slots are lengthwise of the fuse. The actual length of fuse metal must be at least an inch. The rated capacities are the same as for the switchboard circuit fuses, the sizes in common use being

10, 15, 20, 30, 40, and 50 amperes. When placed in the feeder box the length is accommodated by bending the fuse wire around the inside periphery of the mica cup.

Glass-tube Fuses.—The fuse for branch junction boxes and distribution boxes is shown in Fig. 75, *F*.

It consists of a piece of glass tubing 1⅛ inch long, over which a centrally perforated copper tip, ¼ inch long by ¼ inch diameter, is cemented at each end. A piece of 4-ampere fuse wire is threaded through the fuse, turned over at each end and soldered to the tip. The tips fit in the clips of the interior fitting for the junction box.

Sounding tubes which have been used in the Navigational Sounding Machine answer well for the glass tube section.

The fuses are rated at 4 amperes, for 80 volt circuits, and 3 amperes for 123-volt circuits.

Tape.

There are three varieties: pure Para rubber, vulcanized rubber, and cotton tape; each variety is supplied in three widths, ½ inch, ¾ inch, and 1 inch.

All tapes should be of the best commercial grades, of recent manufacture, the surfaces smooth, the body free from holes, the edges straight and without selvage, and the widths even.

Pure Para tape should always be used next the bare copper, when covering a break, splice, etc. It is to be approximately 1/64 inch thick, contain a minimum of 98 per cent of high grade pure Para rubber, and show a maximum of 2 per cent of ash when burned. The color to be brown and the layers separated by paper in the rolls; all rolls to be wrapped first in oil paper and then covered with tin foil.

Vulcanized rubber tape is not suitable for good insulation next a bare wire; it is used as a layer over, and extending beyond, the pure Para tape; being easily injured, it is not suitable for outside layers. It is to be approximately 1/40 inch thick, to contain from 45 to 55 per cent of high grade pure Para rubber, and show from 55 to 65 per cent of ash when burned. The color to be black and the layers separated by linen in the rolls; all rolls to be wrapped in oil paper.

Cotton tape is for use as an outside mechanical layer over pure Para tape, or vulcanized, or both. It is not suitable for the

innermost layer when insulation is required. It is to be approximately 1/50 inch thick, to develop between 40 and 45 per cent of ash when burned. The color to be black and both sides of the tape to be frictioned with a rubber compound. The layers of tape in the roll need not be separated, but the rolls must be first covered with tissue paper and then enclosed in tin foil.

Cotton tape and vulcanized tape are not ordinarily very adhesive, but are made so by warming up moderately after wrapping on.

Inspection of Wiring Appliances.

Ducts.—*Molding.*—Molding material follows the Navy Department specifications for the particular kind of lumber of which it is to be made.

The molding as made is gauged to the dimensions of the drawing, particularly as to gutters and side walls.

The capping design must contemplate securing to side walls and not to the wall between the gutters.

Pine molding must receive a priming coat of paint directly after manufacture.

Conduit.—Conduit is first calipered inside and out and the various lengths are measured. Each length is examined internally against a strong light to detect any fins and burs which would injure wire in drawing.

The ends are to be threaded externally for right-handed couplings; the inner edges must be slightly beveled.

The enamel coating must be of three coats inside and out; this is usually determined on the basis of the thickness and comparison with formerly accepted conduit.

The enamel of three pieces of the conduit is tested by acid; one of each with sulphuric, nitric and muriatic acid, each acid of 30 per cent strength, the duration of exposure to each acid action being 24 hours.

One piece is subjected for 24 hours to the action of a saturated solution of lye. Enamel which resists the action of the acids will frequently soften under the lye test.

A fourth piece of conduit is subjected to a temperature of 100° C. for two hours. The enamel must not soften or run.

A fifth piece is bent cold at a radius of fifteen times the iron pipe size; under this condition the enamel should adhere with smooth surface, and without cracks or knuckles.

Flexible conduit is so little used that it is practically obsolete; what is used is a cotton jacketed hose, whose inspection follows that for hose specifications, the important point being the inspection of the rubber lining.

The rubber compound is to contain 35 per cent fine Para rubber; the composition is tested chemically, and for tensile strength, elongation and permanent set exactly as prescribed for rubber layers of standard wire, and the prescriptions for test are identical with those for wire.

Box Types.—Box types are mainly to comply with standard drawings as to the various details.

Especial attention should be paid to the following:

Boxes and covers must be drilled to jig to guarantee interchangeability and fit of spares.

The box should be thoroughly painted inside with an air drying enamel. This, whilst not demanded by specifications, is important, as the box dimensions have been reduced to the lowest possible limits and the insulating coat is to guard against arcing from the current carrying parts.

The distance between centers of bottom bosses, for holding the interior fittings, must gauge as prescribed by drawing; otherwise the screw holes of new fittings will not register.

The bottom of the box must be well covered by a sheet of mica—micanite in some cases; this is to insulate the block of the interior fitting thoroughly from the bottom of the metal box when the porcelain has absorbed moisture.

Current carrying parts must not be nearer than ⅛ inch to any metal part of the box, including screws. This does not apply to special boxes and is to be regarded as the minimum; the nearness of live parts to the metal is now so small that, for boxes for conduit, not intended to be secured by screws, the screw well bosses, when inside the box, are usually milled off in practice. It is frequently done also with the lower parts of the ribs for the cover screws.

The micanite plate which separates the fuses in special feeder boxes must be secured at the base and not by tongues extending down the sides; the latter case vitiates the required distance for good insulation.

The cloth insertion sheet rubber packing which lines the cover must be so well cemented on as to insure against tearing off at

the edges or from any part of the surface when removing the cover; this is especially to be guarded against when merely edge packings are used.

Box types for interior communication circuits are to comply with drawings, and are inspected as explained for other boxes, as the case may apply.

Non-watertight Appliances.—These appliances except fuses, gaskets and tape, are inspected in comparison with standard sample, being of the general commercial forms.

Fuses.—The main items of consideration in testing fuses is that they shall readily sustain their rated current, shall not blow under a current value of twice the rated value, and shall not redden, nor show excessive elongation under any current value up to that represented by twice the rated carrying capacity for the particular fuse.

A special type of marble panel board is used for the test, on which are assembled: a pair of bus bars; an ammeter; a main line, double-pole, switch; and a "hatchet" switch.

The energy is supplied by three storage batteries at 6½ volts. The positive lead is connected to the main switch through one or more rheostats, having capacities of zero to 10 amperes, zero to 100 amperes, and zero to 400 amperes. Short-circuiting the rheostats gives a total capacity of 700 amperes; when fuses ot greater capacity than 350 amperes are to be tested, the testing is done from the leads of the main switchboard at the test plate (for generating sets).

The ammeter is connected in the positive lead of the main circuit.

The bus bars have in parallel the following appliances for connecting the fuses in circuit: A non-watertight receptacle, for non-watertight attachment plugs; a 4-way branch junction box, for glass tube fuses; a feeder junction box, for corresponding type of fuse; two stud contacts, for switchboard clip fuses; and two stud contacts for dynamo circuit fuses.

The hatchet switch is a special construction having two oppositely placed knife switches, bent back from a right angle, giving the appearance and name, and having a set of clips to the right and left connected to the line; its use is explained in the following example:

Assume that a 200-ampere dynamo circuit fuse is that to be tested.

The fuse is inserted in the appropriate studs of the bus bar, the line is connected up through the 0-400 ampere rheostat and the hatchet switch is thrown to the right hand contact; in this position the current will pass through the line only and not through the fuse. The current is now adjusted by the rheostat until the ammeter shows 200 amperes. The hatchet switch is then thrown to the left, by which the main line current is transferred through the fuse, but by the construction of the switch *the current of the main line is flowing through the fuse before breaking the right-hand connection for the switch;* this necessary arrangement obviates any extra current through the fuse incident to breaking contacts in the ordinary way and the fuse will be subjected only to the actual current in circuit.

The hatchet switch is next thrown to the right (fuse cut out) and the main line current raised to 300 amperes; then the switch is thrown to the left, as before, and the fuse subjected to 300 amperes (150 per cent). In both cases the fuse should not be affected.

Without altering the position of the hatchet switch (fuse still in circuit) the current is slowly raised by the rheostat to 400 amperes (double the rated capacity); the fuse should not blow within from ten to thirty seconds after receiving the maximum.

If the fuse blows appreciably below ten seconds, it is rated too high; if for more than 30 seconds, it is rated too low.

No reddening or excessive elongation should appear at any stage of the test before blowing.

Molded Gaskets.—The specifications for molded gaskets have been cited in the description. Their test follows the same rubber test, chemically, for tensile strength, elongation and permanent set, as explained for rubber layers on wire, for compliance with the specified details. No other test than the gauging of the dimensions externally and of perforations is required.

In selecting a sample for test in the Riehle machine a strip, as long as possible, is cut from the circumference, the cross section being determined by caliper.

Tape.—The rubber constituents are determined chemically as for rubber layers on wire. The percentage of rubber in a weighed sample is obtained by burning the sample; the difference between the weight of sample and ash being accepted as the weight of rubber filling.

CHAPTER V.

GENERATING SETS.

A generating set for the naval service is defined to be the combination of a compound-wound, direct-current dynamo and its operating engine; the two to be direct-connected and self-contained on the same bed-plate. Very recently two 200 k. w. sets have been purchased in which the prime mover is a turbine.

The sets are classified by sizes predicated upon the output of the dynamo in kilowatts and are further distinguished, in commercial classification, or in the manufacturer's standard machines, in types, a division that denotes some improving change in construction from other types; and also by type numbers such as type H-1, type H-2, which indicate some change in the method of construction of details for the same type: the term "form" is more common than "type" in manufacturers' lists.

The sizes, with particulars, for standard navy type generating sets, with general particulars, are contained in the following table:

Size in kilowatts.	Revolutions per minute.	Weight in pounds.	Length in inches.	Width in inches.	Height in inches.
2.5	800	560	32	20	30
5	750	1,300	50	28	40
8	550	2,500	64	34	50
16	450	5,600	78	40	60
24	400	7,300	88	48	68
32	400	10,000	101	52	78
50	400	16,000	110	60	85
100	350	22,000	125	70	95

Commercial types of generating sets are met with in service but are usually installed in naval auxiliaries and colliers only;

they are regarded as special sets and are not included in the standards; they are commonly of 30 k. w., 15 k. w., and 10 k. w. capacities.

Types of the General Electric Company.

The form H type designation of this company is applied to the design of sets having cross-compound, enclosed engines, and may be considered in two varieties: Form H-2, a type in which the governor is inside the enclosing frame; form H-1, having the governor assembled on the fly-wheel outside of the enclosing frame, but which is no longer manufactured. From the manufacturers' standpoint, however, the form H is divided into form H-1, form H-2, and form H-3, the notation being based mainly upon difference in pipe flanges and the method of bolting.

The form H set has been designed in connection with the specifications of 1901 and represents the latest developments of generating sets.

Form H-2, 100 k. w. Generating Set.

The 100 k. w. design of the form H-2 is shown in general arrangement in the frontispiece; a cross-section is shown in Fig. 76.

The set is rated as M. P.-10-100-350, 125 volts; that is, the generator is of the multipolar type, has 10 poles (field core and coils), has a capacity of 100 kilowatts, is designed to have a speed of 350 revolutions, and is designed to generate 125 volts at that speed.

The engine has its cranks 180 degrees apart and has a speed of 350 revolutions per minute (r. p. m.) at full load with 150 pounds normal steam pressure and 25 inches normal vacuum exhaust; it will maintain the prescribed number of revolutions on atmospheric exhaust without alteration of the tension of the governor spring.

The range of steam pressure is between the limits of 120 pounds and 180 pounds. The engine will carry 33 per cent overload for a period of two hours; this contemplates an increase of governor spring tension. Normal steam pressure should be maintained if practicable as this gives best results.

The cylinders are 10 inches (H. P.) and 18 inches (L. P.) in diameter, with a stroke of 10 inches.

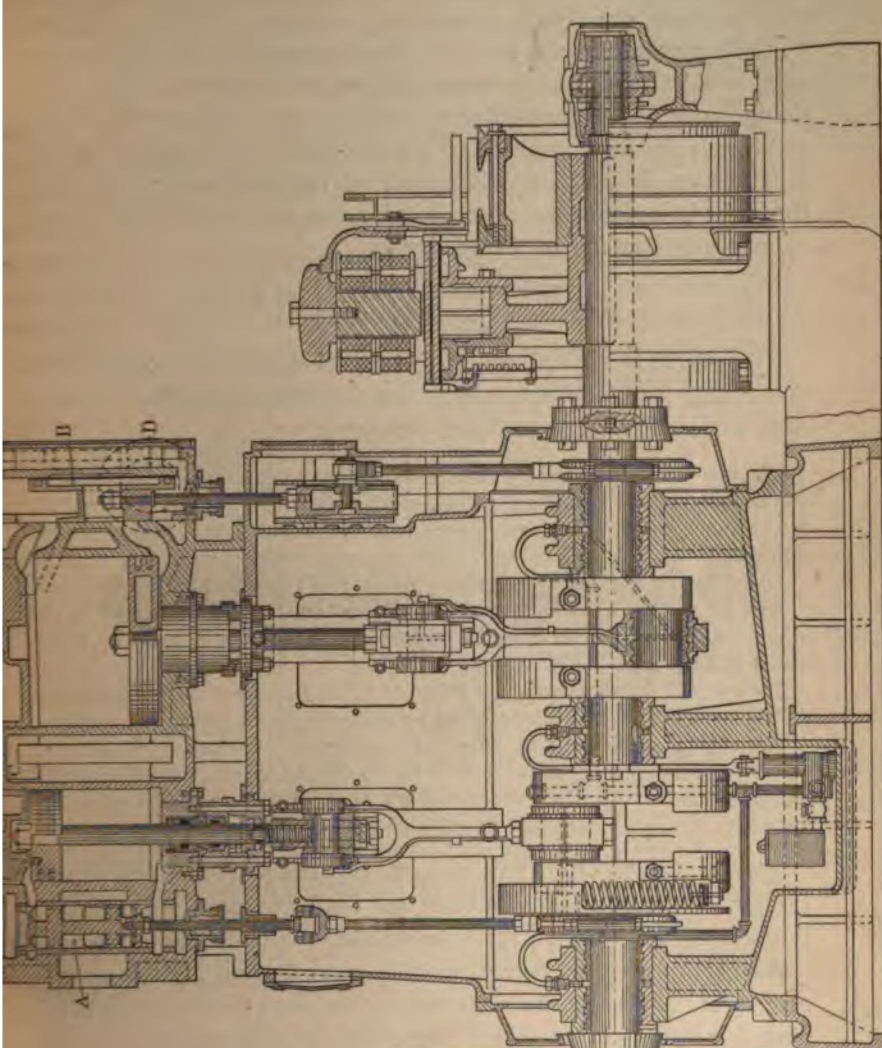


FIG. 76.—Cross-section General Electric Company's Form H, M. P. 10-100-350, 125-volt, Generating set.

The steam distribution is effected through one cast-iron balanced piston valve, *A*, Fig. 76; and one flat, partially balanced slide valve, *B*, fitted with a relief ring to reduce friction. Timed by the movement of the valve, *A*, the steam enters the high-pressure cylinder chest and valve through the throttle valve, and after doing work in the high-pressure cylinder it is exhausted to the receiver, *C*, is then admitted to the low-pressure cylinder, by the L. P. valve, *B*, and is finally exhausted through the passage, *D*, through the exhaust valve to the pipe connecting with the main exhaust pipe leading to the condenser.

The Engine.

The engine is vertical, inverted, reciprocating, cross-compound, condensing and non-condensing, double-acting, variable expansion, enclosed frame, and direct-connected.

[NOTE 9.—A vertical engine does away with any necessity for lubricating the interior of the cylinders and valve chests, and thus ensures against the entrance of oil from that source to the main boilers by way of the condenser; the lack of a cylinder lubricant may occasion wear, but this is provided for by packing rings on the pistons; in any event the renewal of a cylinder lining or cylinder itself is a small matter as compared with injury to the main boilers, which service experience shows must be protected at all practicable hazards.

The enclosed frame (casing) is found to be the best method of preventing the throwing about of oil as incurred by the requisite of forced lubrication.

The engine and dynamo are specified to be direct-connected (now almost universal commercially) as a complete bar to driving by belt, whose slipping occasions loss of overall efficiency and whose tendencies to throw off from the pulley are much enhanced by ship motions and gun shock.]

The bed-plate (Fig. 76) is an iron casting. The upper surfaces at the level of the center of the shaft are machined to take the frame, bearings for the crank shaft, the two flanges of the lower part of the field frame, and the outer bearing for the armature shaft. Between the outer and center shaft bearings the bed-plate is recessed to provide a space for the high-pressure crank, the governor operating the high-pressure valve, the oil pump, and a collecting chamber for the oil in which the pump is submerged. Between the inner and center shaft bearings the bed-plate is recessed to provide a space for the low-pressure crank; this space slants down toward the pump to assist the flow of oil.

Around the outside top edge of the bed-plate is a channel, for catching any oil or water that may escape from any of the joints or openings in the frame. In the front side of the casing are covered hand holes (frontispiece) giving access to the oil pump, the lower level of the oil chamber, for cleaning, etc.

[NOTE 10.—A combination bed-plate, upon which both engine and dynamo are mounted, forms a heavy mass initially for a foundation for both; it secures rigidity for the system and better constancy of alignment of the shaft.]

The shaft bearings (Figs. 76 and 88) are three in number, and consist of cast-iron shells, split in halves. The seats are formed by semicircular recesses machined in the bed-plate; the boxes are dovetailed for casting in a babbitt metal lining. The form of seat and the corresponding form of box admits of the

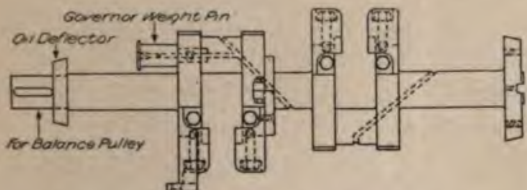


FIG. 77.—Crank shaft, M. P. 10-100-350 set.

removal of the lower half of the bearing by slightly raising the shaft and pressing down on one side of the box; the bearing will then come around to the top of the shaft in a position to be lifted off for examination or repair. The top halves of the boxes are similar to the lower halves and held in place by a cast-iron cap which is bolted to the bed-plate. Over the end bearings are hollow, cylindrical, cast-iron covers with flanges for bolting to the column. The holes in the centers through which the shaft extends, have gutters to catch the oil and prevent its dropping on the shaft.

The crank shaft (Fig. 77) is of one piece of the best forged steel with two cranks at 180 degrees, the bearings being at each side of, and between the cranks; the outer end is turned slightly smaller than the bearing and is keyed to take the fly-wheel; the inner end is flanged outwardly to form the engine half of the coupling connecting with the armature; the flange is drilled for

the coupling bolts. On the outer face of the coupling flange is a boss which matches in a similar recess of the armature flange and ensures alignment; across the face of the flange a seat is cut for a key which relieves the driving strain on the bolts; the outer surface is turned on a bevel to prevent oil from flowing over the coupling from the bearing. Holes are provided in the bearings and crank pins of the shaft for the flow of oil. Cast-iron counter weights are bolted on the cranks to assist in maintaining balance; one of these weights acts as a support for the adjusting screw of the governor spring.

The two parts of the coupling are held together by four 1¼-inch bolts, and are forced apart by two ⅝-inch set screws when it is desired to disconnect the armature.

The axial key is 1-inch square and is secured to the face of the coupling by two 5/16-inch flat-headed screws.

The shaft has a diameter of 5 inches at the bearings and 4½ inches at the fly-wheel end.

The fly-wheel (Fig. 76) is overhung on the shaft at the opposite end from the armature; it is narrow in width and extends radially well to the bottom edge of the bed-plate; the hub is split and clamped to the shaft as well as keyed. The hub extends inside of the casing of the outer crank-shaft bearing and is coned to prevent flowing out of oil. The inside of the rim is flanged inwardly on both sides to retain any oil that may be thrown out.

The enclosing frame (frontispiece) which supports the cylinders on the bed-plate, is of cast iron and has the general shape of a large tapered pipe of rectangular section; it is flanged outwardly at its lower and larger end to attach to the bed-plate, and inwardly at its upper end to attach to the cylinder and valve casting, thus forming a solid top, excepting for apertures for the piston and valve rods; this top also acts as a guard plate.

Around the sides of the enclosing frame are openings with covers affording access to the cranks, cross-heads, and valve rods (see frontispiece). On the back are four bosses, two each for supporting the cross-head slide bar.

The stuffing boxes (Figs. 76 and 78) for piston and valve rods are long and so designed that no part of the piston or valve rods which come in contact with the oil in the enclosing frame shall

enter the cylinder and valve chest, this to prevent the oil, thrown around by the forced lubricating system, from being carried up on the surface of the rods into the steam spaces and continuing thence with the steam over to the boilers. At the point of entry of the piston and valve rods through the upper end of the enclosing frame, a simple form of stuffing box is arranged which acts as a wiper.

[NOTE 11.—The precaution of a long stuffing box and a wiper has been found to be insufficient. In an experiment made on a 50 k. w. engine, to ascertain the amount of oil which actually passed into the low pressure cylinder in 24 hours, the large amount of five pints was recovered in a test oil-separator; this would mean over two gallons per day for each

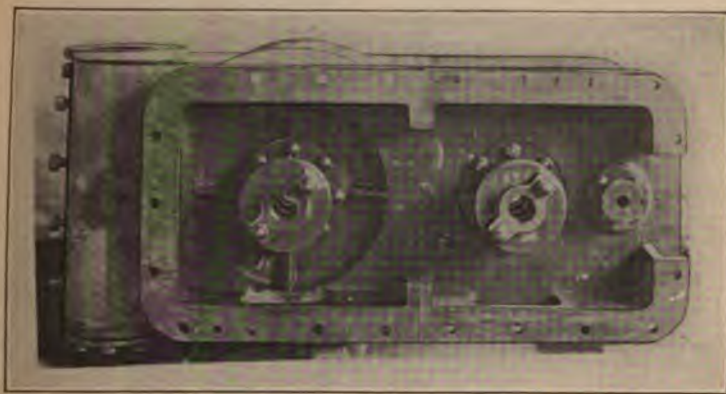


FIG. 78.—Bottom view of stuffing boxes.

100 Kilowatt machine in the ship; the result is undoubtedly due to the suction of the vacuum. For the present, to avoid the conditions, experiment is making by raising the cylinders about 10½ inches, 8 inches, and 7 inches for the 100, 50, and 32 k. w., respectively, necessitating increased length of piston and valve rods, and by improving the efficiency of the wiper; the raising is effected by a cast-iron distance piece; the alteration refers to General Electric sets.]

Rod Packings.—Ordinary soft packing of good quality is sufficient for the valve stem stuffing boxes.

The piston-rod packings are metallic and of either of two types, the United States or the Tripp.

A set of the **United States metallic packing** is shown in cross-

section in Fig. 79. In the bottom of the stuffing box is placed a cast-iron spacing ring or bushing which centralizes the steel spiral spring, *C;* this keeps a pressure on a cast-iron follower, and prevents the rings from following the rod on reversal. The follower fits the rod loosely and carries the pressure of the spring to the three anti-friction metal packing rings 1, 2, 3, contained in the cast-iron vibrating cup *A*. The bore of the vibrating cup is 1/64 inch larger than the piston-rod diameter. The composition of the anti-friction metal of which the packing rods are made is of either of the two formulæ:

Tin	87	8⅓
Copper	8	
Antimony	5	8⅓
Lead	—	83⅓
	100	100

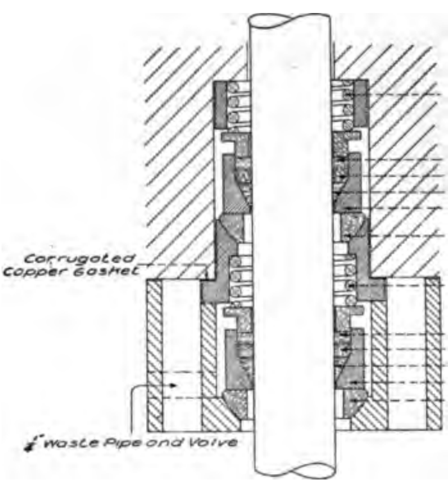


FIG. 79.—United States metallic packing.

These rings are cut in two, after being machined to shape: the "No. 1" ring usually with a separation of 1/32 inch and the "No. 2" and "No. 3" rings with a separation of ⅛ inch to ¼ inch. The joints are staggered in assembling. The lower end of the vibrating cup sets on a cast-iron ring, *B*, forming the ball joint; this joint sets in a curved seat on a cast-iron flanged ring, which forms the dividing gland. Between the gland and the cylinder heads is a copper gasket for making a steam joint.

Below the gland is a similar set consisting of a spacing ring, ring, follower, packing rings, vibrating cup, and ball joint, contained in the cast-iron recessed gland shown by the light shading; this gland is secured to the end of the cylinder by stud bolts. Above the level of the lower ball ring a ¼-inch wast pipe is tapped into the lower gland, as shown, draining off any water that may get by the upper set.

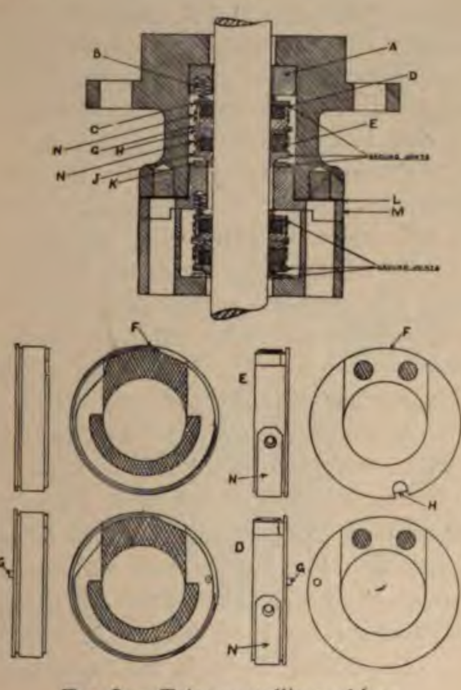


FIG. 80.—Tripp metallic packing.

The principle of the action of this packing is that the pressure of the steam acting upon the spring forces the rings "No. 1" and "No. 2," by the wedging action of their outer surfaces, against the coned surfaces of the vibrating cup and the piston rod. The spring in the upper set supplies about 10 per cent of the pressure.

The Tripp metallic packing, as usually fitted to the high-pressure piston rods of vertical, compound engines, is shown in Fig. 80. The spring case *A* is a ring of cast iron which clears the piston rod, and spaces, in holes on its lower surface, the round

steel springs *B* which hold the sets of packing in position by pressure on the cast-iron ring *C*. The packing rings, *D, E,* are bronze castings and are filled with a special grade of babbitt metal; these are in two parts, as shown, the babbitt being indicated by cross hatching. A pin enters the hole in the end of a flat steel spring *N,* and located at the other end of the spring with reference to the part of the packing *F,* keeping it in contact with the piston rod. Another pin in the upper ring at *G* enters the hole *H* in the lower ring forming the other element of the pair of packing rings, and locating the joints on each with reference to the staggering necessary to ensure against leakage. Below the lower packing ring is a cast-iron "ball," *J,* which engages with the cast-iron "ball ring," *K,* and provides for any vibration or faulty alignment of the piston rod; the surface between the two packing rings will admit of their sliding on each other for the same purpose. A gasket, *L,* and the gland, *M,* complete the first set of packing. The pressure of the parts of the two packing rings against the piston rods is afforded by the steam which enters the space around the ring. The lower part of the packing is similar to the upper and supplements it by acting in case of its failure and also by catching any water that may work through the upper. Such water is drained off by a pipe entering the space around the lower rings; this pipe is not connected to the regular drains as its proper operation requires no back pressure; it is led to a save-all. For low-pressure cylinders the upper set of packing is replaced by a single ring like the spring case *A,* and similarly fitted with springs at its lower side which bear against the gland *M.* The packing is put in the lower section to afford access at the same level as the high pressure.

The cylinder and high-pressure valve-chest casting (Fig. 76) is in one piece and has an extension at its lower end. It is flanged outwardly, to combine with the facility of attachment to the enclosing frame a space for access to the stuffing boxes of the piston and valve rods. The castings are of hard, close-grained cast iron, accurately bored. The lower ends are bored smaller than the full diameter required for the stuffing boxes; this necessitates removing the pistons and the high-pressure valve from the top. The cylinder bores are without liners. The seat for the high-pressure valve is fitted with a cast-iron bush which is re-

tained by being pressed into place. The casting is covered thick with best quality asbestos and lagged with planished sheet iron.

The low-pressure valve chest is separate and is bolted to the low-pressure cylinder.

The throttle valve (Fig. 81) is of the flanged, globe type; it is a 90-degree angle valve, looking upward, and of the Lunkenheimer, regrinding type; the diameter is 3½ inches. It is attached to the casting at the fly-wheel end and can be reached by pipe from either direction. The valve is fitted with a ½-inch by-pass, integral with the body. The valve stem is carried outside of the valve through the yoke; a bolt and gland stuffing box is used.

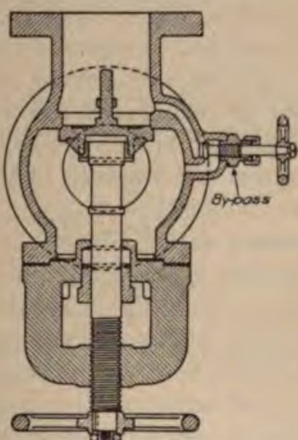


FIG. 81.—Throttle valve.

[NOTE 12.—To regrind the valve seat when worn or leaky. If the main valve, unbolt the bonnet, take the nut from the end of the stem, and remove the hand wheel, after which remove the entire trimming from the valve body. The stem can then be unscrewed and drawn from the yoke. Prepare some abrasive material, such as a little powdered glass, sand, or carborundum, mix it with oil, and apply this to the disc. Make the disc rigid with the stem by inserting a nail or a piece of wire through the drilled hole below the lock-nut. The valve can then be reground by fastening the hand wheel to the stem, the extension of the disc being guided by a bridge in the body of the valve, which will enable the new seat bearing to be reground in perfect alignment. When the valve is reground wipe off all the abrasive material from the seating surface and remove the wire pin from the disc.

The by-pass is not provided with a grinding-in guide; it can be reground with the same abrasive.

All other valves on this engine are of the union bonnet construction; it is unnecessary to remove the stem from the valve trimming, as the hub of the trimming should guide the body and keep the stem in line with the seat, otherwise the regrinding is effected as above.]

The exhaust valve can be attached to the extreme end of either side and be reached by pipe from either direction. This valve is also of the Lunkenheimer type.

The heads for the top of the high-pressure cylinder and high-pressure steam chest are combined in one and are finished off by a polished, light, iron hood casting.

The head for the low-pressure cylinder is separate, and is also finished off with a polished hood.

The high-pressure and low-pressure cylinder heads are fastened to their respective cylinders by twelve ⅞-inch studs and nuts; the flanges of both heads and low-pressure steam chest cover are tapped for two ¾-inch eye-bolts for lifting off.

The cover of the low-pressure valve chest is a flat casting heavily ribbed at the outside.

The high-pressure valve (Fig. 76) is of the solid piston type, single-ported, variable travel, and balanced by being surrounded by steam; it takes steam at the center between the heads. There is no adjustment for leakage except by turning down and replacing the valve-chest bush, as the valves are solid. The steam lap is ⅞ inch top and bottom; the exhaust lap, top and bottom, is zero. The travel of this valve is controlled by the automatic governor, and varies between 3¾ inches and 1⅝ inches. The cut-off varies between ¾ inch and zero, depending on the load.

The low-pressure valve (Fig. 76) is of the flat, single-ported, constant-travel type, balanced by an annular surface on the back in which is fitted a ring which is pressed out by springs against a bearing surface on the side of the steam chest cover; it takes steam at the inside and exhausts at the ends. The steam lap is 1¼ inches; the exhaust lap, top and bottom, is zero. The valve travel is 3¾ inches, giving a cut-off of about half stroke.

The high-pressure piston is shown in Fig. 82. It is a cast-iron disc containing two rectangular grooves, which receive the packing rings of the type as shown in the figure. The piston is taper-bored to take the rod, as shown, fitting against a shoulder

on the piston rod, and is secured to the rod by a nut on its upper side; the outer face of this nut contains radial grooves, one of which engages a split pin which prevents the nut from unscrewing. The **low-pressure piston** is also of cast iron, the general construction being the same as that for the high pressure, excepting that the piston is cored instead of being solid. The **piston packing,** or packing rings, as shown, consist of cast-iron arcs, three sections for those used on the high-pressure piston and four for those used on the low pressure. The arcs overlap at the ends and are made steam tight by brass tongues, one of which is riveted to each arc. The packing is held tightly against the cylinder wall by flat springs ⅜-inch wide and 1/16-inch thick, secured to the arcs by machine screws.

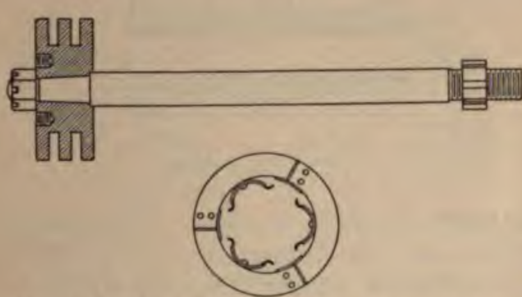


FIG. 82.—Piston, piston rod, and piston packing.

The piston rods (Fig. 82) are of nickel steel, and are threaded to a less diameter than the body of the rod at the lower end where they screw into the cross-head and are locked by a jam nut. The threading into the cross-head affords a convenient means of adjustment of the piston clearance at both ends of the stroke. The diameter of both the high and low-pressure rods is 2¼ inches.

The cross-head (Fig. 83) is a mild steel forging. The cross-head shoe, *B*, is of composition metal, babbitted, and has a liberal wearing surface, that the wear may be reduced. The shoe is secured to the cross-head by two 1-inch bolts and is held against the guide bar by the clamp, *C*, which is secured to the shoe by six through bolts, the proper distance between the shoe and the clamps being adjusted by liners, *D*. The cross-head is slotted to receive the wrist pin bearing, *E*, which is made of gun metal, and held in place by the cap, *F*, and two bolts secured by the lock-

nuts, *G*. The upper part of each nut is turned circular and fits in a recess in the cap; set screws, *H*, prevent the nuts from turning, and set screws, *J*, prevent the turning of the bolts. Wear is taken up by filing the edges of the brasses, and, on account of the system of oiling which is used in this engine, it is important that

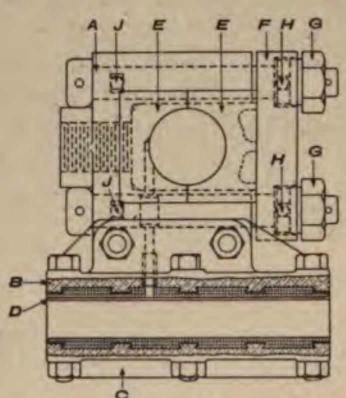


FIG. 83.—Cross-head.

these edges should always be together. The bearing should be so adjusted that, when the brasses are hard together, the wrist pin will move freely but without play. Oil reaches the bearing from the oil pipe, *G* (see cut of connecting rod), passing up the side of the connecting rod; from this bearing the oil is forced further to the guide.

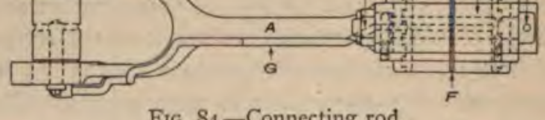


FIG. 84.—Connecting rod.

The connecting rod (Fig. 84) consists of a forged steel body, *A*, forked at its upper end to receive the wrist pin, which is shrunk into the connecting rod. The lower end of the rod terminates in a stub, to which the crank-pin box is secured by a steel cap, *B*, and two 1-inch forged steel bolts, *C*, held by lock nuts, *D*. Split pins pass through the ends of these bolts, preventing the lock nuts from coming off.

The crank box, or crank-pin bearing (Fig. 84), is a hollow, cylindrical, cast-steel shell, *E*, split in halves. The shell has two small flanges which fit the connecting rod and prevent the shell from moving sideways; it is prevented from turning by through bolts which make a guide for it. The inner surface of the shell, which comes in contact with the shaft is babbitted and wear is taken up by removing the fiber liners, *F*.

As the oil must be forced from this bearing up to the wrist pin and cross-head guide, it is important that the boxes are always tight together or there is likelihood of leakage of the oil.

The wrist pin, or cross-head pin (Fig. 84), is of machine steel, case-hardened and ground; a small groove is cut at the two points where it joins the inside of the fork of the connecting rod.

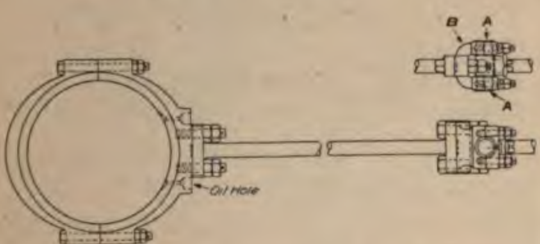


FIG. 85.—H. P. eccentric rod and strap.

It is bored at one end for an oil way to the center of its length; at this point it meets a through, vertical cross-bore which admits the oil to each half box.

The high-pressure eccentric is an iron casting which is split to embrace the shaft; it swings in an arc whose center is a bearing pin of machine steel, cases-hardened and ground and pressed into the side of the high-pressure crank. The governor weight is cast solid with the high-pressure eccentric.

The low-pressure eccentric is an iron casting, split to embrace the shaft, and secured to it by two set screws.

The high-pressure eccentric rod and strap, with forked brasses, which are in three pieces, are shown in Fig. 85; the rod is round steel. These brasses are secured to the upper end of the eccentric rod, and the lower end of the rod to the top half of the strap, by two ¾-inch studs. The halves of the strap are separated by liners, for removal for adjustment for wear.

The bearing caps, *A*, are each secured by studs and double nuts, fitting brass and brass, wear being taken up by filing the cap faces.

The low-pressure eccentric rod and strap are of the same general construction as explained for the high-pressure rod and strap with the exception that the brasses are in two pieces instead of three.

The guide for the high-pressure valve stem is of cast iron; it is bolted to the engine column, and is fitted with a composition metal bushing which is pressed into the guide.

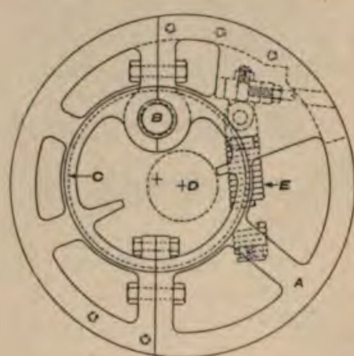


FIG. 86.—Governor.

The valve rods, or **valve stems,** are of steel, larger in the center when in contact with the two stuffing boxes, and reduced at each end.

The upper end of the **high-pressure valve rod** is screwed into the body of the valve and secured by a lock nut; the upper end of the **low-pressure valve rod** passes through the valve and is secured by double 7/8-inch nuts on the upper side. These nuts should be locked hard together, *but the stem should be free to turn in the valve,* though without any play. The rod is fitted with a taper washer which permits the valve to adjust itself on the stem.

The valve rods are threaded at their lower ends and secured by lock nuts. The **high-pressure rod** is screwed into the small cross-head (Fig. 85). The central portion of this cross-head is square with cylindrical ends, forming a bearing with the forked link, *B* (Fig. 85), which is bolted to the upper end of the eccentric rod. The **low-pressure rod** is screwed into the body of the

valve rod slide which has a bearing in the cast-iron guide bolted to the engine column.

The governor is of the Rites dumb-bell type, modified to suit the conditions occasioned by the swinging eccentric and the limited diameter which is available inside the frame and bed-plate. (See notes on generating sets for description of the Rites design.)

The governor is shown in Fig. 86, and consists of a single fly-weight, *A*, in halves, which are securely bolted together and pivoted, at *B*, to the main bearing pin, which is driven into the crank and secured by a set screw as shown in the illustration of the crank shaft (Fig. 77). The fly-weight is supplied with a loose brass bushing, which provides a double bearing surface. The pin and bushing communicate with the inside of the engine and are, therefore, always under an oil pressure which minimizes the chances of sticking or binding.

[NOTE 13.—This matter of good lubrication is the great advantage of an inside governor, out-weighing by assurance of good working the convenience of being more accessible when outside of the casing.]

The operation of the governor is as follows:

The eccentric rod and strap (Fig. 85) which transmit motion from the governor to the high-pressure valve, are connected to the eccentric, *C*, which forms a part of the fly-weight casting. It is evident that the length of the valve stroke (travel of the valve) depends upon the distance of the center of the eccentric, *C*, from the center of the shaft, *D*. The amount of steam which will be admitted to the cylinder by the valve will, then, vary directly as the distance between the centers for *C* and *D*; that is, the less the distance between those centers, the less the amount of the valve travel and the less the amount of steam admitted, and *vice versa*.

Suppose now that the dynamo is suddenly relieved of some large amount of current supply, thus relieving the engine of an important amount of its load, the engine would immediately tend to speed up under the existing head of steam; this speeding up would cause the fly-weight, *A*, to be immediately thrown out by centrifugal force from the shaft, thus decreasing the distance between the centers of *C* and *D*, the length of travel of the valve would be thereby decreased, less steam would be admitted to the cylinder, and, the head of steam being decreased, the engine must

slow down; that is, the tendency of the engine to speed up has been counteracted. It should be especially noted that, the greater the tendency to speed up, the more the distance between the centers between *C* and *D* will be decreased until this distance is reduced to its practicable minimum (not quite coincidence, however) when the valve will practically close the ports and admit almost no steam at all. This action, therefore, protects the engine against dangerous racing.

The outward swing of the weight under centrifugal force is controlled by the heavy coil spring, *E*, which is attached to a bracket cast with the crank-shaft counterbalance; this provides a method of regulating the speed to that for which the engine (actually the dynamo) is designed to run. By ***increasing the tension of the spring*** the tendency of the outward swing of the weight is resisted, the travel of the valve is less readily decreased, and the effect is to ***increase the speed;*** from similar reasoning a ***decrease of the tension of the spring*** will ***lower the speed;*** the same effect will be produced by moving the spring in the slot provided for it in the weight—moving the spring ***away from the fulcrum*** increases the speed, and moving towards the center produces the opposite effect.

[NOTE 14.—Although unstable regulation of speed is due principally to too close an adjustment of speed, and may be remedied by moving the spring attachment *away* from the fulcrum, the process requires skill and care; it is the experience of those handling the Rites design of governor that, where the regulation remains unstable after careful adjustments by the spring, it is a difficult matter to obtain the exact point of relation between spring and fulcrum adjustment when their effects are combined; that is, fulcrum adjustment requires long practice. It is common practice for engine builders, lessees under the Rites patent, to submit the question of a design for a governor of the particular size and type to the experts of the Rites corporation and obtain all details of construction and adjustments from them; this does not necessarily assure the success of the governor without assistance of experts. **Fulcrum alterations should not be permitted aboard ship.**]

Relief valves are attached to each end of each cylinder and in connection with the drains (Fig. 87). The valve is held to its seat by a spring adjustment made through the set screw at the top, which is tapped through the head and fastened by a jam nut; the set screw bears down upon a spring head (see also drainage system below).

The drainage system is shown in Fig. 87, in which the connections, the 1-inch relief valve, swinging check valves, and three-way indicator cock are for the high-pressure cylinder (see also frontispiece). The 1½-inch relief valves for the low-pressure cylinder are of the same general construction.

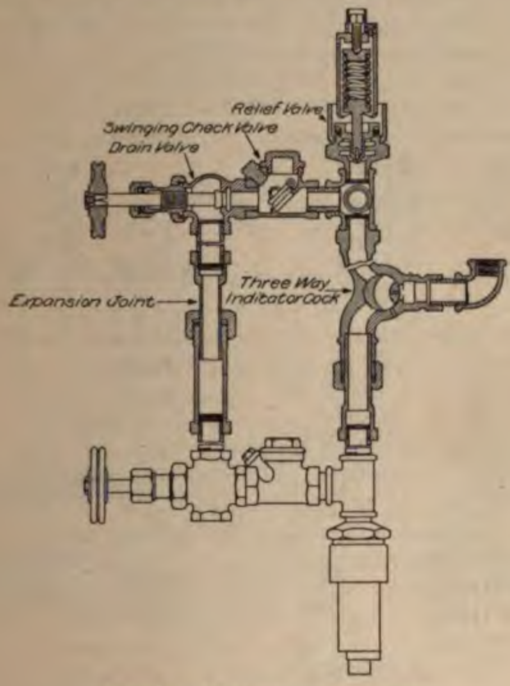


FIG. 87.—Drainage arrangement.

Indicator Motion.—When a card from the engine is desired, a small cover (see frontispiece) must be removed from the front of the engine column, exposing a slot over which a bracket containing a bearing pin for the levers is attached. Each cylinder has its individual indicator motion consisting of a stud for driving the motion and which is screwed into the wrist pin of the connecting rod, this connects through a link to a lever pivoted to the bracket covering the slot in the column. The motion for the indicator barrel is taken from the card pin on this lever.

The Forced Lubrication System.—The lubricant is carried under pressure to the various part of the engine by the mechan-

ism shown in Fig. 88. The bed-plate of the engine forms an oil reservoir (Fig. 76) to which is attached a small plunger pump, driven by an eccentric on the shaft, and receiving oil from the reservoir in the bed-plate through a strainer (Fig. 76). The oil is forced by this pump to grooves in the main bearings (Fig. 88), and drilled holes connect these grooves with the crank pins, the oil being further forced to the wrist pins through the pipes on the side of the connecting rods (Fig. 84).

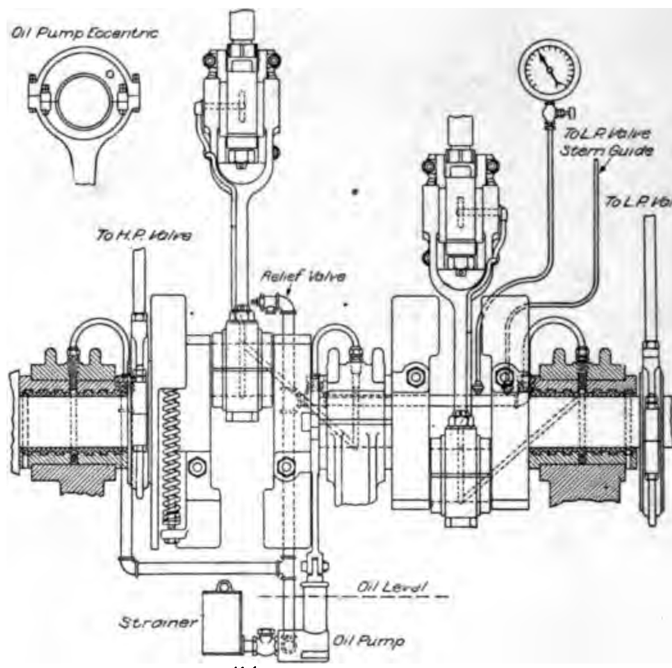


FIG. 88.—Forced lubrication system.

The passages in the cross-heads (Fig. 83) permit forcing the oil from the wrist pins to the guides, as shown.

A pressure gauge is attached to the system to indicate the oil pressure delivered by the pumps. The best working pressure is from 10 to 20 pounds and is made adjustable by the relief valve (Fig. 88) which is provided with an adjusting set screw at the back of the engine where the valve projects through the engine casing.

The oil in the reservoir should stand about 3½ inches over the suction and discharge valves and be freed of water by running through the oil filter.

[NOTE 15.—The forced lubrication system for high speed engines is now recognized as a great improvement on methods of gravity sight feed lubrication in preventing hot bearings, reducing wear to a minimum, and minimizing attention.

It is important that the oil be free from all substances such as particles of waste or grit; and, to guard against the introduction of any foreign matter, a strainer is attached to the suction valve of the pump, which may be taken out for examination or cleaning at any time whether the engine is in operation or not.

It is not necessary, nor desirable, to keep the pressure gauge in circuit continuously; it is intended more as an instrument for testing the pressure from time to time.

Only mineral oil should be used for lubrication; that which has stood the test for even small machines and over a range of years is Arctic Engine Oil. As the oil passes through the bearings repeatedly, it gradually loses its lubricating qualities, becoming thick and gritty and mixed with water, and should be run through a filter and mixed with new oil; the frequency of this change depends upon the oil as well as the number of hours the engine is in operation; it can be determined by observation for the particular case and ship, and should be part of the established routine of every dynamo room.

The oil level in the reservoir must not be high enough to permit the cranks or counterbalance weights to strike in the oil; the oil thrown about within the engine casing from leaks under pressure is rather more than is desirable as it is; the lubrication is amply sufficient as designed and splashing the oil by fast turning cranks and weights only causes foaming and heating. A good rule is to have the oil level from 1½ to 2 inches below the lowest plane reached by the crank or counterbalance.]

The Generator.

All the generators of the General Electric Company's manufacture have an armature of the slotted core, barrel-wound type, in sizes below 100 k. w., the armature is usually series-wound; that for the 100 k. w. is multiple (or parallel) wound. The 100 k. w. has ten or eight poles; the 50 k. w. of the form H design, eight poles; the 50 k. w. of the tandem-compound set, six poles; the 200 k. w. turbo-generator has four poles and four inter-poles.

[NOTE 16.—The slotted-core construction is now very general; its main advantages over the "smooth body" armature—in which insulated wires

are wound round the armature core ring (Gramme ring winding)—are: *first*, superior induction, the slotted core designs developing in the teeth about 116,000 lines of force per square inch and 92,000 in the magnet core as compared with 80,000 to 85,000 in the best designs for the Gramme ring; *second*, better mechanical construction, inasmuch as the armature circuits are sunk in the slots and wedged in by the top-sticks, the whole being held firmly by the binding wires; the conductors on the periphery of the armature are thus removed from danger of mechanical injury, a menace in the smooth-body assembly, if the shaft be out of line by bringing the periphery of the armature too near the pole pieces, the periphery of a slotted-core armature is the metallic edge of its core discs, the conductors being farther protected by the top-sticks; *third*, the gap space, or radial distance from the pole piece to the conductors can be lessened, thus decreasing resistance in the magnetic circuit and strengthening the magnetic flux, and at the same time the net radial distance from the periphery to the pole pieces is increased, giving better mechanical clearance; *fourth*, the conductors are protected from the injury of the heavy torque in case of short-circuiting of the armature winding.

The selection as to series winding or multiple winding in an armature for ship use is mainly a question of reaction, that is, output. In the larger sizes of these direct-current generators the multiple winding is practically a necessity for the reason that there are no features in the two-circuit (series) windings which tend to subdivide the current equally between the different brushes of the same sign. Consequently, if there is any difference in contact resistance between the different sets of brushes, or if the brushes are not set with the proper lead with respect to each other, there will be an unequal division of the current and excessive heating of the windings. For example, suppose two conductors to be paralleled, each having a resistance of one ohm and each carrying a current of 100 amperes, the heating effect in each will be 10,000 watts, or, for both, 20,000 watts ($200^2 \times \frac{1}{2}$), but if from unequal contact, one carries 120 amperes and the other 80, the heating will be $14{,}400 + 6{,}400 = 20{,}800$ watts; hence the effect of unequal division of the current in the two paths increases the total heating effect and materially increases the heating of that path which carries the excess current. When there are as many sets of brushes as poles, the magnetic density at each pole must be the same, otherwise the position of the different sets of brushes must be shifted *with respect to each other* to correspond to the different intensities. In practice it is found difficult to prevent the shifting of the current from one set of brushes to another; the possible excess of current at any one set of brushes increases with the number of sets, likewise the possibility of excessive sparking, and for this reason the statement has been sometimes made that the disadvantages of the two-circuit windings increase with the number of poles. In the case of multiple windings, the drop in any circuit, as well as the armature reaction in the field in which the current is generated, tends to prevent the excessive flow of current from the corresponding set

of brushes. The principal advantage of the multiple-drum winding over the series-drum is the relatively lower voltage per bar, which becomes very important in large direct-current generators; as a comparison consider an 8-pole 300 k. w., 100 r. p. m., generator generating 550 volts, details would be:

	Multiple-drum.	Series-drum.
No. of slots	272	204
Conductors per slot	6	2
No. of commutator bars..	816	204
Volts per bar	5.6	22.5

An 8-pole series-drum winding, therefore, requires but one-fourth the face conductors of the multiple-drum; it being necessary in the design of the example cited to reduce the number of commutator bars to 204, the voltage per bar, if wound series-drum, would be prohibitive.

The multipolar construction has several advantages over the bipolar:

I. Stray field, from the poles, is minimized, a consideration in ship use.

II. The total permissible current is divided up into a convenient number of k. w. per magnetic circuit, permitting large outputs. (It is convenient in this connection to look at a multipolar construction as so many machines in parallel per pair of poles; that is, an 8-pole machine would be regarded as four separate machines in parallel; this convenient method is not, however, strictly applicable.)

III. The areas for radiation of heat from the armature, commutator and field coils are increased, permitting the material to be worked to greater activity.

IV. The magnetic circuits are shorter, requiring less weight of copper and magnetic metal.

V. Less space is required.

As regards the number of poles a generator is to have, a simple, rough rule for other than very large machines or especial cases, is to allow a current density of 100 amperes per set of brushes, or per pole; this determines the number of poles as being the quotient of the total full load current divided by 100, the next higher even number being used. This would assign the number of poles, neglecting the requirement for 33 per cent overload, at 125 volts, as follows: 100 k. w., 8 poles; 50 k. w., 4 poles, and lower sizes at 4 poles arbitrarily, in order to be multipolar, with probably but two sets of brushes for 24 k. w. and less. A large number of poles tends to reduce the tendency to sparking, but it adds to the size of the generator and hence to the weight. The 100 k. w. machines now have 8 poles, though the first made were designed for 10 poles. The 50 k. w. machine has 6 poles instead of the 4 calculated; but the machine is really a 75 k. w. machine on commercial rating of a heat rise of 40° C. in the armature, and for 75 k. w., 600 amperes are required at 125 volts; hence, for 6 poles the rule is verified in this case also.]

The generator develops 800 amperes at 125 volts normal rating, but is capable of carrying 1067 amperes at that voltage for two hours. It is shown in cross-section in Fig. 89 and is separable in description into two distinct parts: *The field assembly*

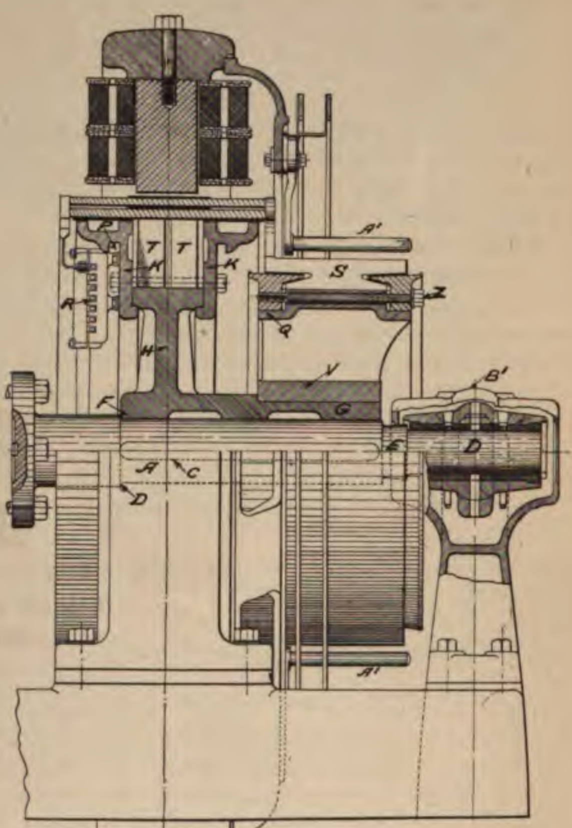


FIG. 89.—Cross-section 100 k. w. generator.

(including the frame, poles, or field magnets and carrier, or rocker) and the *armature;* these two parts are also the two electrical divisions as the frame is a part of the magnetic system of the field cores.

The Field Assembly.

The frame (frontispiece) is circular and is a two-piece casting. It is extended down on each side to form feet cast in one with the lower half of the frame; the two halves of the frame are connected together by two bolts on each side which are not visible, being entered through pockets in the bracketing of the feet; this pocket is covered by a sheet-metal cap. The base of the feet are planed to rest on a liner on the planed surface of the bed-plate, and to this the feet are secured by two bolts through liner and bed-plate; the upper half is similar to the lower with feet omitted.

The carrier (frontispiece) is a circular casting with lightening holes, which fits into a guide recess on the commutator side of the frame and is prevented from moving out of the recess by the cylindrical end of ⅜-inch filister head cap screws, which engage

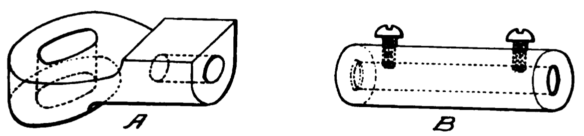


FIG. 90.—Connecting lug and wire connector.

in a groove in the frame; on the upper inner side a toothed segment is fitted, which engages the pinion of a shaft extending through the frame; this shaft is operated by a hand wheel to vary the lead of the brushes on the commutator within required limits. The two collector arcs for opposite polarity are rigidly secured to the carrier as are also the 10 studs for the 10 sets of brushholders. The brush leads for the total armature current are connected to the collector arcs and are led loose to two hard rubber blocks or boards, secured over and near the top of the frame (Fig. 91). One block carries the connections for the positive brush and line leads and the leads to the rheostat; the other carries the negative brush and line leads and the lead for the equalizer; it has also a connection for the return from the rheostat, if desired to connect short shunt; on board ship, however, the negative from the rheostat is connected at the switchboard, or by long shunt.

All the leads connecting to the boards and collector arcs have their ends soldered into a connecting lug (*A*, Fig. 90), which can

be securely bolted by copper bolts; this assures good electrical contact in each case.

The generator name plate is usually placed on the frame; the armature number is on the end of the shaft.

The poles, a section of one of which is shown in Fig. 89, consist of a core, a series-winding, and a shunt-winding. The whole assembly is secured to the frame by a single bolt, which is tapped into the center of the core, thus permitting the backing out of the bolt, and removal of a complete pole assembly without removing the armature.

The core is a cylinder of soft cast steel, turned to fit against the interior surface of the bored frame; and, at the armature end, concentrically with the radial distance from the center line of the armature shaft. The pole pieces, or shoes, are cast solid with the cores.

The field windings, series and shunt, are separately wound on spools; the spools are slipped on over the cores before the cores are placed and are held in place by the projecting shoes; the shunt winding spool goes on first, next to the frame. In each spool an annular space is left in the center of the winding (Fig. 89) for ventilation.

The Series Coil.—The *series winding* consists of 6½ turns per coil of strip copper 2¾ inches by .075 inch, arranged five in multiple. The weight per coil is approximately 58 pounds; the cold resistance is .000118 ohm.

The coil is wound on a form. Before beginning the winding .14 inch of pressed board is placed around the form to allow for wrapping space. The "I" ("inside") series lead is first soldered on and insulated with a wrapping of five thicknesses (turns) of varnished cambric, each turn being coated with shellac to hold the turns together; beneath the "I" lead are placed two thicknesses of varnished cambric to prevent the rivet heads from working through the insulation on the bottom of the coil. The winding is then begun, a piece of .03-inch leatheroid being placed between the "I" lead connection and the first turn of the copper. The first two turns of copper are insulated with one thickness of .008 muslin of sufficient width to lap over the top of the form; the coil is then clamped, removed from the form, and insulated by wrapping around it two layers of varnished cambric, lapped

one-half. A piece of 8-ounce duck is next sewed on under the "I" lead, of sufficient length to extend to the top of the second turn of copper, under which the coil is wrapped with one thickness of 1-inch stay-binding, lapped one-half. The coil is then replaced on the form and wound with two turns of bare copper; between these turns are placed the space blocks to form the annular ventilating space, and of such thickness as will round out the coil. The winding is then resumed, the .008-inch muslin insulation being placed between the turns. Before cutting the copper used in the winding, the "O" ("outside") lead is riveted and soldered on, and is insulated in the same manner as the "I" lead. After this, there are placed under the last turn six lots, four cords each, of No. 7 boot thread, equally spaced, and extending about 12 inches beyond each side of the copper.

Four of the copper strips are then cut off, the remaining strip is neatly covered with No. 2 cotton drill and is wound completely around the coil when it is riveted to the coil beneath it and cut off; the coil is then removed from the form. Veneer collars are fitted to the coil and holes are drilled through them at the points at which the six lots of cord are located. The collars are then tied tightly to the coil by the cord, after which a lacing of cord, consisting of three turns, is placed around each arm in the ventilating space and is tied and cut off. The coil is dipped in air-drying japan before being assembled on the field core.

The Shunt Coil.—The *shunt winding* consists of 585 turns of No. 10 B. & S. G. single-cotton-covered wire. The weight per coil is approximately 72 pounds; the cold resistance is .78 ohm.

The coil is wound on a form. On the form are placed two thicknesses of No. 2 cotton drill of such width as to cover the body of the form and extend 3½ inches up each side. The portion extending up the side of the form is cut into small tongues of approximately ¾-inch width; the tongues of the two layers are staggered. To the drill is added on thickness of varnished cambric and one thickness of oiled asbestos. Four layers of wire are then wound on the form and the tongues of the upper layer of the cotton drill are turned down over the winding. The winding is then continued until the ventilating space is reached, when the tongues of the first thickness of cotton drill are turned down and the winding is completed to within two layers of the top of the

coil. At this point, pieces of cord are placed on the coil as described for the series coil, after which the winding is completed; the terminals are then soldered on and the coil removed from the form. The coil is dipped in air-drying japan before being assembled on the field core.

When the poles are assembled on the frame the series coil of each pole is connected to that of the next pole by bolting together the copper strips leading out from the series winding; the shunt

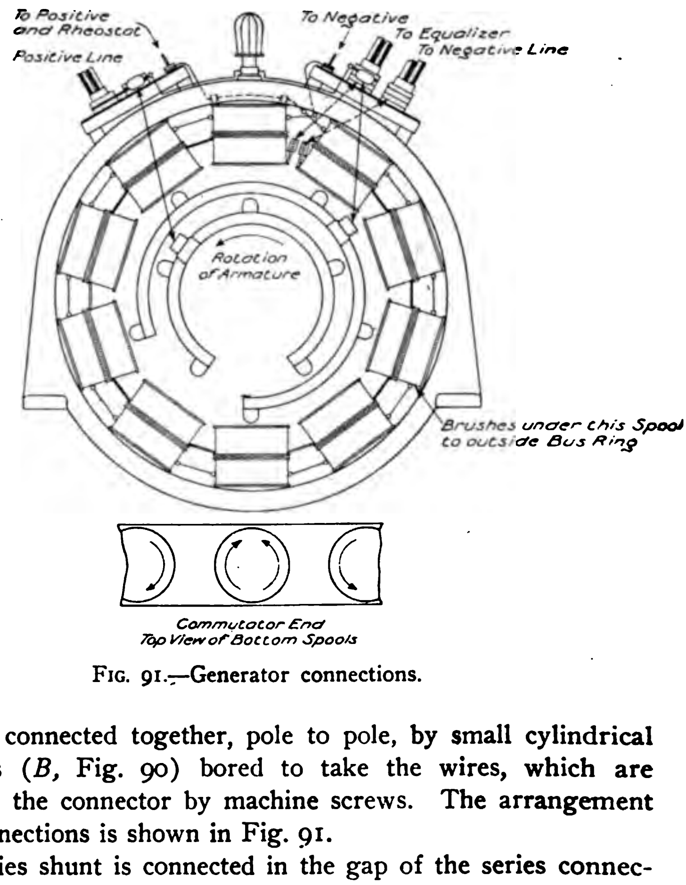


FIG. 91.—Generator connections.

wires are connected together, pole to pole, by small cylindrical connectors (*B*, Fig. 90) bored to take the wires, which are secured in the connector by machine screws. The arrangement of the connections is shown in Fig. 91.

The series shunt is connected in the gap of the series connections shown below and to the left of the negative board; it is then brought up and back of the frame. It is made of German silver resistance ribbon and, after the resistance is adjusted, is fitted with terminals for bolting in the gap.

[NOTE 17.—The action of the series shunt is more readily explained in the effect of the field winding as a whole on the terminal voltage of the generator's armature. In (Fig. 92), since the armature, due to the shunt winding, will generate its full voltage, at rated speed, before any current circulates in the line, all curves will start at *A*. Were the armature to continue to operate under its shunt conditions alone, the terminal voltage would drop as the current increased producing a curve similar to *AC*. The straight line *AB* would be the theoretical condition for constant potential, but in view of the fact that even compound machines tend to somewhat decrease in potential as the load increases, the curve *AD* is what is practically desired. To obtain the curve *AD*, by the increments *ab*, *cd*, is the office of the series field and these increments will increase in value, from the point *A* to the designed limit of load, proportionately to the increase of current. The combination of shunt and series field thus keeps the voltage constant and causes the generator to be self-regulating.

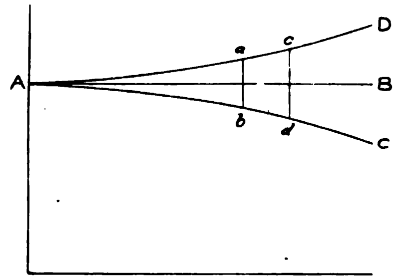


FIG. 92.—Diagram of characteristic of a compound-wound dynamo.

It is not practicable to mechanically adjust the exact resistances of the shunt and series windings to the nicety essential to the case, and two methods of field regulations are adopted: *the first* is, the introduction of a practically constant resistance shunted across the series field, which will steady the voltage under normal heated conditions of the armature and field windings at any load; *the second* is, from considerations of economy and efficiency, to reduce the field current by inserting a rheostat in series with the field winding which will cut down the voltage at the field terminals to the voltage required, and to so design the rheostat that a part of its resistance may be adjustable and thus afford a means of compensating for irregularities of speed, temperature, etc., when the generator is in operation.

The series shunt is therefore intended to be a fixed nonadjustable resistance shunted across the series winding which will assure that those increments of voltage which are added by the series field to the voltage produced by the shunt field will keep the terminal voltage within the permissible variation at any stage of load. The shunt rheostat affords in its adjustable resistance all necessary means of keeping the terminal voltage to its rated value under operating conditions.]

The Armature.

The principal parts of the armature are the **shaft**, the **spider**, the **armature core**, the **commutator**, the **armature winding**, and the **brush assembly**, including the connector arcs attached to the carrier.

The armature shaft (Fig. 89, *A*) is of steel and turned down its whole length except at the engine end where the flange for the coupling is forged in one with the shaft; the flange is slotted to take the radial driving key. The shaft is turned ½ inch larger, *D* (to 5½ inches), next the coupling, which affords a shoulder for the spider, *F*. The center portion of the shaft is of the same diameter as the crank shaft, 5 inches; this portion takes the spider and is fitted, *C*, with a key-way for a driving feather; the right-hand end, *D*, is 4½ inches in diameter, and is for the bearing of the self-oiling sleeve, or ring-oiler bearing. Intermediate between the bearing and the spider is an enlarged taper-turned portion, *E*, designed to prevent oil from flowing toward the armature from the bearing surface of the ring oiler.

The spider, *F*, is of cast iron with three bearing surfaces on the shaft. The hub of the spider is elongated at *G* to take the commutator; this device also reduces the possibility of any flexure of the connections between the windings and the commutator. From the hub of the spider six legs, *H*, extend to the inner surface of the armature core; in one of these legs is placed a key-way for a feather (not shown), which drives the core disc positively. The legs are joined together by two cast-iron rings, *K*, which extend up to the line of the slots and are flanged outwardly at the top to support the extension of the windings which project beyond the slots, and inwardly at the bottom to secure under the T-shaped section top of the spider leg. These rings, *K*, are drawn together by bolts against space blocks bearing on the armature core discs, and thus draw the core discs together. The ring, *K*, on the back of the armature is provided with an annular recess, *P*, to retain any oil that may crawl along the shaft from the engine bearing.

The armature core, of a total length of 4⅞ inches, is made up of two sections, or discs, *T*, which are separated from each other and from the rings, *K*, by space blocks, the interior spaces thus formed affording a system of three ventilation ducts through

the core; these space blocks, are metal castings, consisting of a ring on which are placed radial arms carrying the actual blocks and fitted over the keys on the spider leg; the space blocks are held in place by the pressure of the spider heads.

The core discs, or sections, two in number, as shown, are made up of the thin discs which are stamped out of pure wrought-iron sheet and laminated to form the sections, the lamination affording means of breaking up Foucault or eddy currents which would tend to heat the core; the laminations are about .025 inch thick, and are japanned on both sides; each core section is 2¼ inches thick. The slots for the armature winding and key-way for the spider leg are stamped into the discs and when the sections are pressed into form the key-ways and slots are trued up by filing; the inner and outer lamination of each section has teeth for securing to the space block, but the discs are not bolted together, being held in shape by the pressure of the space-block rings and bored next to the spider for the through bolts from the rings, *K*.

The commutator is mounted on the extension of the hub of the spider and is driven by a key. The shell, *V*, is provided with arms which admit air through the commutator, thus cooling it and also assisting in keeping up a current of air through the interior of the armature. The inner end of the commutator shell, *Q*, toward the armature core is flanged off, and two of the surfaces are finished at suitable angles to support the back of the commutator bars. The front end is fitted with a similar ring which clamps the commutator bars together and is drawn in by bolts, *Z*. The commutator bar is shown in longitudinal section at *S*; it is made of hard-drawn copper and is insulated from the shell by mica. The back of the upper surface of the commutator bar is milled to receive the ends of the leads or connectors for the windings, ½. The commutator is 30 inches in diameter and 10⅜ inches long, giving good radiating surface for the heat of friction and resistance losses due to the use of carbon brushes.

There are 350 commutator bars, or two bars per slot.

The armature winding is of the multiple-drum type and consists of 1400 conductors of bar copper .07 inch by .075 inch. There are eight conductors per slot insulated from each other, and before being placed in the slots, on the lap-wound principle, they are formed together, the method being known as the Eickemeyer winding.

[NOTE 18.—Generally speaking, bar windings in an armature are preferable to wire windings as they permit of lower heating guarantees and higher efficiencies due to the fact that more copper can be placed in a given slot; a wire winding would have a number of air spaces between the wires, whereas with a bar winding these air spaces would be reduced to a minimum and filled with insulation only. Bar windings are not practicable with small generators for mechanical reasons; for example, a 10 k. w., 500-volt machine would have approximately 20 conductors per slot, requiring 10 clips per slot, and their connection would be mechanically impossible. The limitations of the employment of the bar or wire for armature windings is the size of the conductor and the number of conductors per slot; if the cross-section of a conductor exceeds that of a No. 4 B. & S. G. wire, and the number of conductors per slot are 8 or less, a bar winding is preferable.

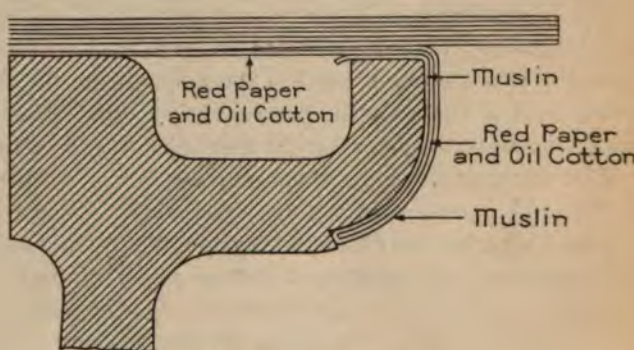


FIG. 93.—Flange insulation.

The Eickemeyer type of winding consists essentially of a series of insulated coils exactly alike, with the portions on the end of the armature core so formed that, where two adjacent coils cross each other, there will be a space intervening between the underlying portion of one coil and the overlying portion of the other. It has several advantages: there is absolute uniformity in the winding construction, as the formed coils are alike; the coils are firmly secured and not so likely to abrade the insulation as in other forms of drum-winding which are more or less loose; the coils are readily removable and interchangeable, hence repairs are easily made; there is more uniformity in resistance in the several circuits; there is economy of space; and more perfect insulation is practicable. In the Eickemeyer method the windings are laid on, or wedged into, the periphery (into the slots), and are clamped in place by bands screwed to the back and front of the armature, or merely held in the slots by the clips and connectors, making a decided improvement over the usual drum-winding; as compared with the Gramme ring-winding, not drum-wound, only those conductors are used which are represented by the peripheral part of that type of winding and cross-magnetization is lessened.]

Where the ends of a winding are to be connected to the commutator bar they are soldered to a copper clip which embraces the two ends; the lower edge of the copper clip is pinned and soldered in the milled slot of the commutator bar.

The armature insulation is generally considered in three divisions: the **flange insulation,** which refers to insulation over the flanges of the rings, *K,* Fig. 1; the **slot insulation,** and the **insulation of the bar conductors,** or **insulation of the winding.**

The method of **flange insulation** is illustrated in Fig. 93. Over the end of the flange is placed one layer of muslin, one end being

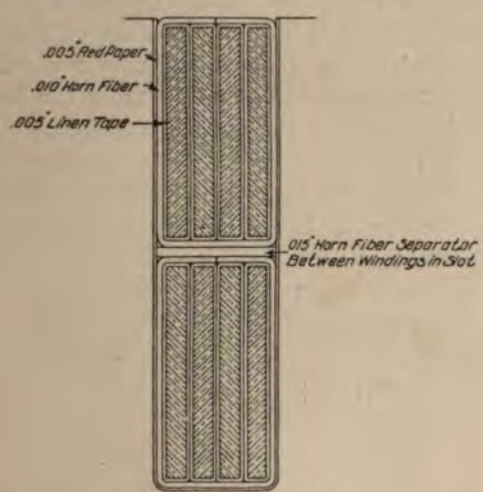


FIG. 94.—Slot insulation.

allowed to remain hanging. Over this and extending the entire width of the flange are placed three layers of red paper, each .009-inch thick, and two layers of oiled cotton, each .007-inch thick, arranged alternately, paper first. This insulation is of sufficient length to fold over the end of the flange, where it is pasted, after which the end of the muslin remaining hanging is brought up and over this insulation, forming a finish. Layers of pressed board are placed over this and built up flush with the bottom of the slot.

The insulation of each slot (Fig. 94) consists of one piece of .005-inch oiled red paper cut to such a size that when pressed into the slot it will project about ½ inch above the top of the

slot and ⅜ inch beyond each end. After the coils are in place the insulation projecting beyond the top of the slot is trimmed off flush with the surface of the armature.

For the **insulation of the winding** (Fig. 94) each bar is taped with .005-inch tape butted through the slot part and one-half lap outside of the slot. Each bar is then brushed with shellac over the slot part with 2½ wraps of .006-inch varnished bond paper with the lap on the top. Over this is cemented a .010-inch piece of horn fiber (Fig. 94) with the edges butted in the center on the top of the coil. Between the upper and the lower layers of the winding in the slot is placed a .015-inch horn fiber separator which projects ⅝ inch beyond the ends of the slot. Between the windings outside of the slot and over the flanges are placed .020-inch fiber separators extending from the armature punchings to the inside of the clips which connect the top and the bottom layers of the winding. Over each of these separators is laid a narrow piece of .030-inch horn fiber placed close to the clips.

The commutator leads are not taped but are given a coat of air-drying japan.

No top sticks are used in the slots of this armature.

The binding wire consists of two bands over each section of the armature core, and two bands over each flange. The four flange bands consist each of 12 turns of .072-inch steel wire; the inner bands over the sections are of 10 turns each of .042-inch phosphor bronze wire.

Equalizing Rings.—A feature of this generator is the use of equalizing or balancing rings, shown in section in Fig. 89, *R*, on the back of the armature; their object is to maintain the brushes of the same polarity at the same potential. They are sometimes called Lammé rings.

[NOTE 19.—The explanation of the use of equalizing rings is as follows: In large multipolar, multiple-wound, direct-current, machines, the potential generated in a conductor under one pole sometimes exceeds or falls below that in a similarly situated conductor under another pole of the same polarity. This may be due to difference in the pole strengths at the two poles; to differences of winding and construction; the armature may not be central in the magnetic field (out of magnetic balance) from the sag of the shaft or from magnetic pull on the bearings; or the brushes may make unequal contact on the commutator; the result is that a current corresponding to the difference of potential till flow from one section of the winding to the other through the brushes. This current will act in the same way as

if two generators were rigidly connected on one shaft and the potential of one was raised above that of the other, the former would run the other as a motor; the result of the unbalanced current is bad sparking, excessive heating of the windings and burning of the brushes.

The actual method of equalizing the brush potentials by equalizer rings is shown in the large armature of Fig. 95. The rings are continuous conductors secured to the back of the armature and insulated from it.

FIG. 95.—Example of armature with equalizing rings.

A diagram of the general method of connecting is shown in Fig. 96. From the winding at the periphery, and in sections corresponding to the number of pairs of poles, connecting leads from parts of the winding, which in the different sections will be simultaneously in the same position in regard to the fields, are tapped to the same equalizing ring. Hence if any difference of potential exists for any part of the winding tapped to the ring, the ring forms a short path for equalization independent of the windings or brushes. The current which will flow will be seen to be an alternating current, leading in some coils and lagging in others, enabling a small current to establish the balance. The armature will be in magnetic

balance with important variations of position in the field due to lack of alignment of the shaft; in fact *such an armature will not indicate that it is not central in the field by a test for magnetic balance.*

The following somewhat extreme cases of the effect of equalizing (Lammé) rings have been reported:

An electrolytic generator ran for two years with one of the shunt exciting coils reversed.

A generator, 810 k. w., 180 volts, 4500 amperes, ran for three weeks with two coils reversed without material difference in performance.]

The Brush Assembly, or Brush Rigging.—Ten brush studs, two of which are shown in Fig. 89, A^1, A^1, are tapped into the carrier, or rocker, and on each stud are fitted five brush holders each carrying one carbon brush.

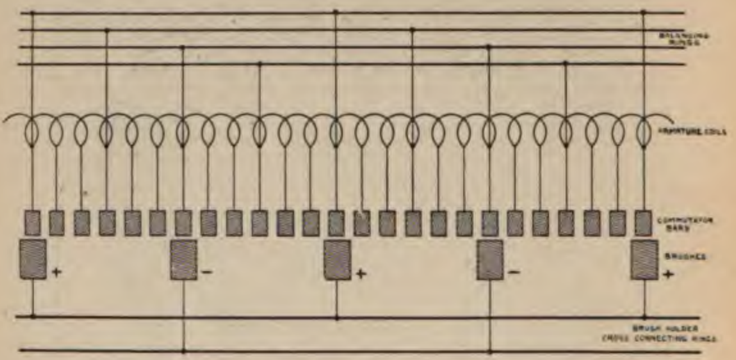


FIG. 96.—Diagram of method of connecting equalizing rings.

The brush holder is shown in Fig. 97. It consists of a brass casting having a bore which is machined to slip on over the brush-holder stud, the bore is split at one side and sprung to be tightened or loosened on the stud by a screw. On a barrel in the jaws of the casting is a stiff steel spring whose end is curved and extended to take on the top of the brush, the pressure being regulated by a lever operating the barrel, and which lever can be retained in place by pawls on one side of the jaw. To one end of the casting is secured a cast or bent brass box having flanges to bolt to the former casting. A screw on top of the casting secures the clip of the connector or "Pig Tail" of the brush.

In securing the holder on the stud care should be taken that the lower, beveled edge of the box holding the brush is parallel to the surface of the commutator.

The brush (Fig. 97) is of carbon and is 1¼ inch by 1 inch by 1½ inch. It is coated with copper for three-fourths of the length and is capped with a piece of brass. The connector or

FIG. 97.—Brush holder and carbon brush.

pig tail is soldered to this piece of brass and to its other end is soldered a copper tip, whose jaws embrace the set screw on the top of the holder.

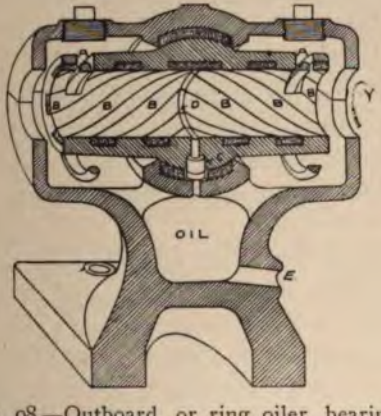


FIG. 98.—Outboard, or ring oiler, bearing.

The Outboard Bearing (B^1, Fig. 89).—This is also called the pillow block bearing and the ring oiler bearing. The bearing is shown separately in Fig. 98.

The bearing itself is a sleeve held in the pillow block by a ball

and socket joint, and hence is self-aligning. The lower part of the pillow block forms a reservoir for oil. Two slots in the upper part of the sleeve are cut transversely, one near each end, exposing the upper surface of shaft at these places. Two rings (*AA*, Fig. 98) dipping below the surface of the oil in the reservoir, rest on the exposed parts of the shaft and are driven by it. The sleeve is cast iron. On the bearing surface of the sleeve, spiral grooves (*BB*) are cast, running right-handed from one and left-handed from the other end. These grooves are filled with babbitt metal, the bearing surface thus consisting of spiral bands, alternately babbitt and cast iron. A groove (*D*) is cut around the middle of the sleeve, where the spirals meet; it communicates with the oil reservoir by holes (*C*) in the ball of the sleeve and the socket bearing of the pillow block. The oil may be drawn off from the reservoir by a pet cock screwed into a hole (*E*) in the pillow block.

When a machine with bearings of this construction is running, the motion of the shaft keeps the rings (*AA*) continually revolving and carrying oil from the reservoir to the ends of the bearing. The oil delivered at the ends of the bearing is swept towards the middle of the sleeve by the action of the revolving shaft on the spirals. At the middle of the sleeve the oil is collected by the groove (*D*) and returns by the hole (*C*) to the bottom of the reservoir where it has time to settle and cool.

Depending only on the motion of the shaft, the oiling action of this bearing is entirely automatic. Starting the machine starts a flow of oil through the bearing which is continually maintained whilst the machine is running and stops the moment the machine is stopped.

An arrow is cast on the upper surface of the sleeve, and the latter must be set so that the upper surface of the shaft runs in the direction the arrow points.

It is recommended that these bearings should be examined once a week, although the oil does not need to be renewed as often as that.

[NOTE 20.—The action of the carbon brush in producing *natural*, or *resistance commutation*, and of the pole pieces in producing *forced* or *magnetic commutation* (both methods being combined in the design of the 100 k. w. generator), are to ensure sparkless commutation in the operation of the machine.

Natural, or Resistance Commutation.

The very general use of carbon brushes is due to the greatly reduced sparking at these brushes as compared with copper; the larger number used is due to the difference in carrying capacity, for while a current flux of 250 amperes to the square inch may be allowed for copper brushes, only from 30 to 40 amperes to the square inch are allowed in carbon designs, and in practice it is found to be better to keep below the lower limit. The necessary carrying capacity is obtained by putting more brushes on the same stud. For high-speed commutators a higher current density is usually preferable, in low speed commutators a lower current density.

The better service of carbon brushes in producing sparkless commutation is, in some details, still a matter of controversy; the difficulty seems to be in examples taken from different designs which have been constructed on the various theories, and from which an actual, final determination has not been exactly crystallized; in short the empirical factors form the contention in view of the fact that the mathematical are too involved for integration.

The voltage generated in the armature of a constant potential, direct-current dynamo is actually an alternating voltage; constant, non-alternating potential is effected by "commutation," which is obtained by dividing the armature winding into a number of divisions, or separate coils, whose ends are connected in series by attaching the end of one coil to the beginning of the next, through connections at a segment of the commutator, and taking off the current by means of brushes. The brushes change, "commutate," the tendency to assume the negative values of alternation and make them positive; the complete revolution of any single coil, therefore, produces cycles which are not alternations of positive and negative directions of the current, but a succession of positive directions. Perfect commutation for constant potential would consist in having an infinite number of coils and thus prevent the pulsations of practice; but mechanical considerations, and the necessity of insulation between the commutator bars, limit the number of coils in practical design.

In the act of commutating, or reversing, the current, the sparking of commutation is produced, and may be of two kinds, the non-deleterious or "blue-spark," and the deleterious, "vicious," or yellow spark; the blue spark appears because the current producing it is small, while the yellow results from the heating effect of a current sufficiently large to volatilize the copper of the commutator bar and be carried to that edge of the bar which the brush leaves; this will account for the increased sparking with increased load. As the melting and volatilization takes place at the side of the bar which first comes in contact with the brush, that edge will be left smooth and no sign of injury will be noticed until sparking begins; this seems to explain why a machine, originally commutating sparklessly, will show sparking after a little use, and why the sparking can be stopped temporarily by turning down the commutator.

The problem of sparkless commutation resolves itself into automatically preventing the current producing the volatilization of the copper of the

[illegible]

[illegible]

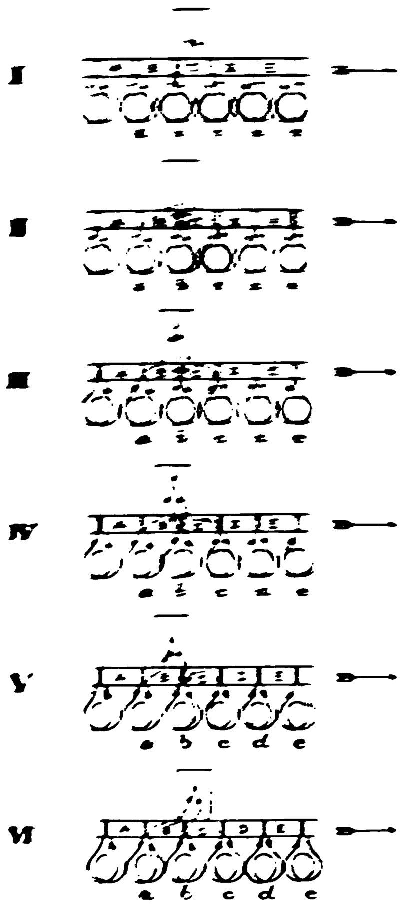


Fig. [illegible].—Illustrating resistance commutation.

the purpose of illustration. A current is assumed to be flowing into the negative brush, and to be dividing itself to flow up both sides of the armature, the direction of flow in the coils *a*, *b*, *c*, and *d* being indicated by the arrows.

In I are shown the conditions when the brush is in contact with the segment *C* only, and when the currents from each side of the armature

are collecting in the brush without other hindrance or effect than the resistance of contact between the brush and the commutator bar.

In II one fourth of the brush contact has passed over from *C* to *B;* the current in the coil *a* has been afforded a short path to the brush and its current no longer passes through *b;* the coil *c* still passes its current into the brush; the coil *b* has been short-circuited, as the brush now bridges both segments *B* and *C*, to which it is connected, and no current due to that coming from the negative brush is circulating in it. Just as the brush came in contact with *B*, however, an electromotive force was generated in *b*, due to self-induction, and a current was set up in the closed circuit of *b* proportioned to this electromotive force and the resistance of *b*, which is tending to gradually discharge itself.

III and IV are the conditions when the brush area of contact is one-half and three-quarters on *B*, respectively, and in which the paths for the current from *B* has proportionately less resistance and that from *C* proportionately greater; the induced voltage in *b* has meanwhile been discharging itself.

In V are shown the conditions just as the brush is to leave the segment, *C*, when the contact area of the brush on *C* has become very small and has introduced a large resistance, comparatively, to the flow of current from *C* to the brush; the current now divides itself in inverse proportion to the resistance, part going into the brush direct from *C*, and part going through the coil *b*, which is assumed to have (or should have) discharged its induced current.

Considering the conditions of V, if the current which is passing direct to the brush from *C* is comparatively large, it will, when assisted by the electromotive force induced at the time of the breaking of the contact of the brush with *C*, have sufficient value to cause a spark to arc over from *C* to *B;* the value of the current which, just before breaking contact, was passing from *C* to the brush, will depend upon the resistance afforded by the area of the brush. If the material of the brush be *solid* copper the resistance afforded will be low and the value of the current will be comparatively high; if the material be *copper leaves* or *copper gauze*, or the entering and trailing sides be reinforced by a strip of resistance metal such as German silver, the resistance will be greater than that for solid copper and the tendency to sparking will be decreased; if the material be *carbon* the resistance will be high and the value of the current proportionately low and comparatively insufficient to cause a spark.

In VI is a condition, intermediate between I and II, in which the status is the same for the moment after contact of the brush with *B* as *V* is for moment before breaking contact with *C;* only a small part of the current from *a* is flowing into the brush from *B*, while the major part goes by way of *b*. As the current due to the voltage of self-induction is flowing into the block, *B*, in an opposite sense to that coming directly from *a*, it opposes the current coming from *a* and reduces its value; hence, there should be less tendency for a brush to spark deleteriously in making contact on its entering edge, the tendency is limited to the trailing edge only;

there would be heating but the temperature would not be great enough to produce a spark.

Two things are, therefore, necessary in resistance commutation to sparkless commutation: *First*, the induced current must have discharged itself before the brush has broken contact with *C*, this the material of the carbon brush assists by giving high resistance in the short circuit. The element of time is an essential factor in assuring this discharge, and the time between making contact at *B* and *C* is extended by making the brush width greater; the brush is usually made wide enough to space two to three bars of the commutator, but the width is affected by the general design of

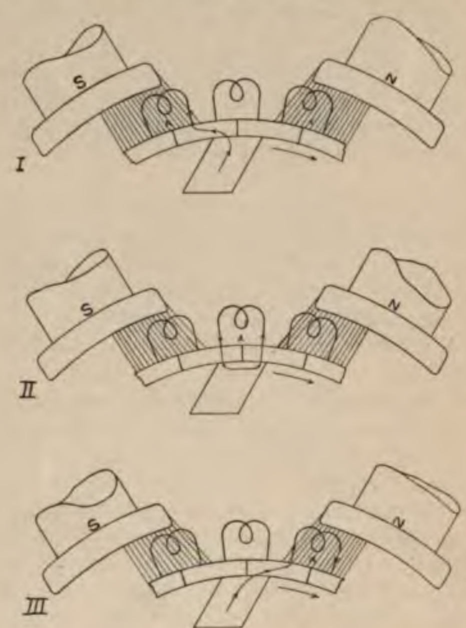


FIG. 100.—Illustrating magnetic commutation.

the dynamo. *Second*, the resistance to the flow of any current from *C* to the brush at the time of breaking contact should be great enough to reduce the current to zero before the break occurs; evidently carbon is preferable to copper for the purpose.

Forced, or Magnetic Commutation.

This method is that which is due to the effect of the "fringes" or magnetic lines of force from the pole pieces. A coil leaving the magnetic field of a pole and entering that of another is under three conditions, as shown in (Fig. 100), I, II, and III.

In I the coil *A* is under the field of the pole, *S*, and is generating a

voltage which is taken from the commutator bar through the brush (placed inside for illustration) in the direction of the arrow.

In II the coil *A* has left the field of the coil *S* and has progressed in rotation to *B*, where it is short-circuited by the brush now bridging the two commutator bars to which the ends of *C* are connected.

In III the coil *A* has entered the field of the pole, *N*, and its current now circulates in the opposite sense to that of the position of *A* in the field of *S*. The arrows indicate the circulation of current in the coil in the two positions.

In II the current flowing around *A* when short-circuited is not one generated due to the field but only to self-induction; in order that there be no sparking, as the right hand segment of the commutator, to which *A* is connected, leaves the brush, it is necessary that this current be reduced to zero and built up again to circulate in an opposite sense to that before short-circuit; to accomplish this, the pole pieces are shaped to have the effect of fringing out the field of *N* toward the position of *A-B* and thus bringing *A* gradually under the influence of its field. Applying this to the fringe of *S*, the field action would be to delay the waning of the current in *A* to nearer the point of short-circuit and sustain the voltage; but the feature desired is the early reversal of the current in *A* between the point of commutation and the dense field of *N*.

That forced commutation alone has not proved successful in obviating sparking, with varying load and fixed position of brushes, points to the fact that resistance commutation is the important factor within the limitations of its adaptability to the particular design and, as before shown, carbon brushes accomplish the greater part; the efficiency resides in the resistance of contact.

Carbon brushes introduce a loss in generator efficiency due to the resistance of contact and to friction, both largely in excess of the values obtained with copper brushes; but the general efficiency of operation, without change of brush position with load, have made it commercially desirable to increase the radiating surface of the commutator to keep the extra heating within acceptable limits, the increased cost and loss in efficiency being offset by the advantages of operation.]

There are designs of the form H type of the General Electric Company, having inside governors, for 75, 50, 32, 24, and 16 k. w.; and all the sizes, except 75 k. w., are installed or in use in the service. The engines of all sizes are modelled on the 100 k. w. with variations in parts according to size but carrying out the general plan.

The generators below 100 k. w. are series-wound, wave-wound, drums, having a lever arm rocker which can be locked by the lever; the connecting arcs are used in all.

A 100 k. w. set for the *Georgia* showed:

Engine efficiency	92.7 per cent.
Dynamo efficiency	90.8 per cent.
Overall efficiency	85.0 per cent.
Water consumption (k. w. hour)	27.5 pounds

The governor regulation of speed and voltage complied with specifications over the whole range of steam pressures and vacua for the variations of load.

The compounding came well within permissible variation, and once set at a lead of 8 bars, 1.88 inches, there was no sparking between no load and 33 per cent overload, no change being made in the brush position.

CHAPTER VI.

GENERATING SETS (Continued).

Form G—General Electric Company.

This type is generally spoken of as the tandem-compound combination, from its style of engine; the M. P.—6-32-400, 80-volt design is shown in Fig. 101. After eight years' service experience it appears to be commonly agreed amongst those who have had to do with its operation and repair that this type of generating set has proved most satisfactory. The remark is derived mainly from the endurance in operation of its engine, the modern dynamo requiring little repair, accidents apart, during the life of its brushes and commutator. The engine, having fewer working parts than the cross-compound, has a good margin left within the limits of weight for a strong, sturdy construction, and ample bearings. It proves to operate quietly and continuously under a minimum of repair and adjustment; it shows good efficiency and economy after ordinary use; the wear of parts is small with large surface and forced lubrication; and it has the distinct advantage of a reduced number of small working parts to be replaced, or get out of order, or break—an important matter in vessels of war whose personnel is continuously changing, and whose immediate available skill for operating and caring for the particular plant may be somewhat in question.

The objection to the tandem-compound type of engine which has debarred it, in that the official specification prescribes a cross-compound, is the head-room required in the compartment on board the ship in which it is to be installed; in the light of recent developments as to accession of oil in the cylinders the objection is much modified for generating sets of 50 k. w. and under, as there will hereafter be but unimportant difference in height between the tandem and cross-compound types; for a size of 100 k. w. the height necessary to the tandem-compound engine would probably be too great for present-day ship dynamo rooms; there has been, however, no design of a tandem-compound gener-

ating set of over 75 k. w., commercial capacity, at 125
which last is the same in its engine as the 50 k. w. size at 8(
There is a difficulty which is to be remembered in conı
with the tandem engine construction—it is more a difficult
an objection—and that is the difficulty in removing the in
diate head between the cylinders. While the difficulty may
obviating the necessity, the stuffing-box between the cy

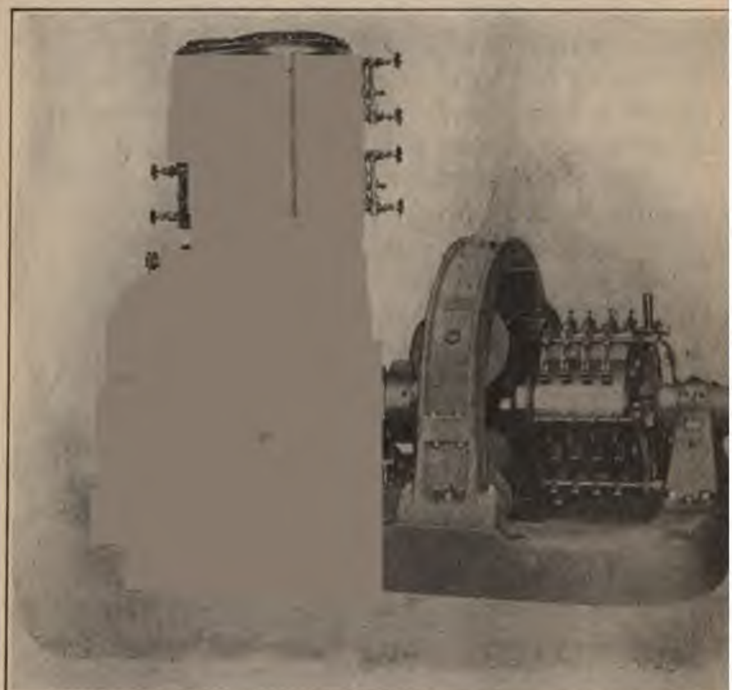


FIG. 101.—General Electric Company's Form G (tandem-compo
generating set.

(and through the intermediate head) has no other lubri
than that derived from the steam, and the intermediate
requires to be taken out when repair and thorough exami
of the stuffing-box is necessary.

The standard line of designs embraces the 50, 32, 24, a
K. W. sizes.

Features of the Engine.

The engine is shown in cross-section in Fig. 102. The steam pressure is 100 pounds; rated exhaust, 25 inches or atmospheres.

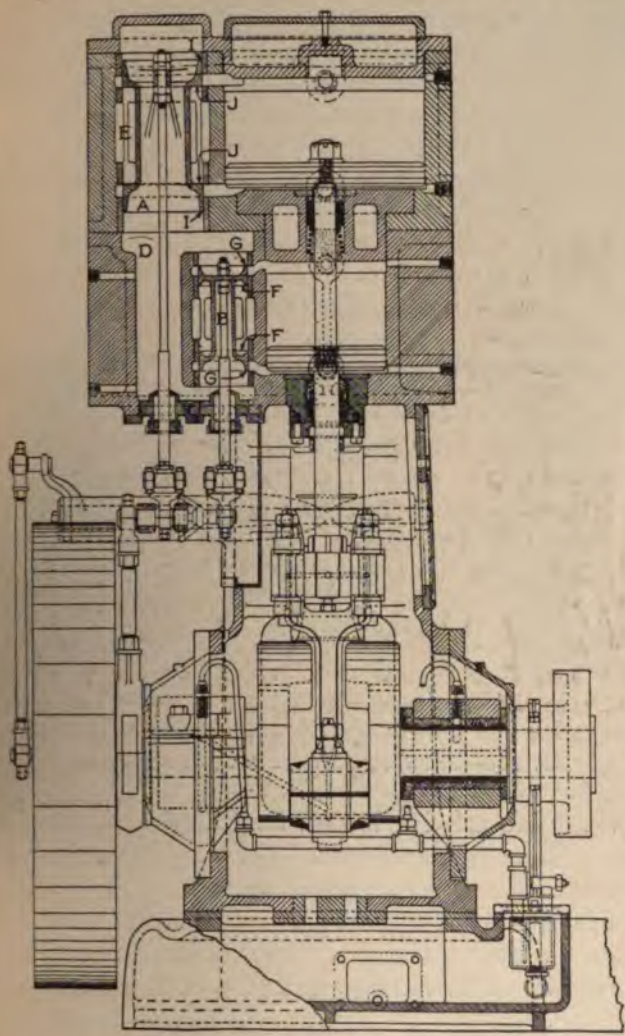


FIG. 102.—Cross-section tandem-compound.

The **steam distribution** is effected through two cast-iron, balanced, piston valves, *A* and *B*. Timed by the movement of the

valve *B*, the steam enters the high-pressure cylinder chest and valve through the throttle valve, and after doing work in the H. P. cylinder is exhausted into the receiver *D*; thence, it is admitted into the low-pressure cylinder by the valve *A*, the steam passing through the body of the valve *A* when admitting to the top of the L. P. cylinder; the steam is finally exhausted through the passage *E*. The H. P. valve takes steam on the inside, the admission edges being at *FF* and the exhaust edges at *GG*; the steam lap is ¾ inch; the exhaust lap, top and bottom, is zero. The travel of this valve is controlled by the governor and varies

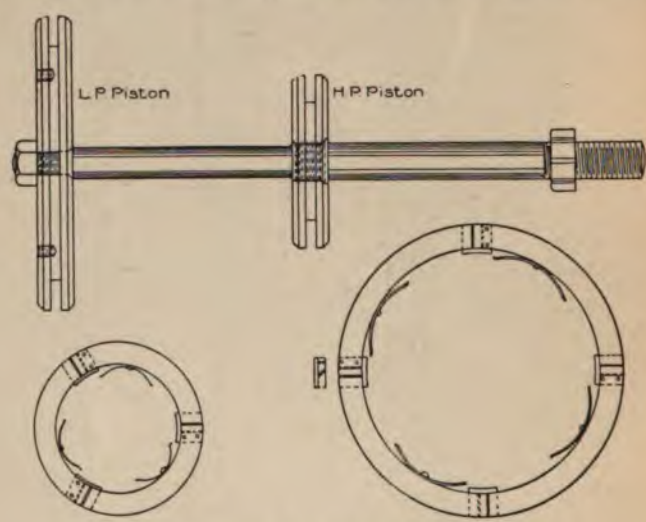


FIG. 103.—Pistons, piston rod and piston packing.

between 3 inches and 1⅜ inches; the cut-off varies between ¾ and zero, depending on the load. The low-pressure valve takes steam on the outside, the admission being at *II*, and the exhaust edges at *JJ*; the steam lap is 1 1/16 inch and the exhaust lap is, top, zero; bottom, 1/16 inch. The low-pressure valve has a fixed stroke of 3 1/16 inches, giving a cut-off in the cylinder of about ⅝ stroke.

The casing or column is tapered and made strong to support the cylinders and is well secured to the bed-plate. A door gives entrance to the interior and casings enclose both shaft-bearings.

There is but one **crank**, hence only two main bearings are neces-

sary. The shaft coupling is in one with the shaft, with usual provision for the radial key and bolts; at the opposite end the fly-wheel—carrying the governor—is overhung on the shaft and between this wheel and the casing is bolted the eccentric for actuating a rock-shaft, which in turn operates the low-pressure valve. There is also an eccentric between the coupling and the casing; this operates the pump for the forced lubrication system.

The shaft-bearings are similar to those of the form H.

The low-pressure piston (Fig. 103) is a cast-iron disc with a single rectangular groove, which receives the piston packing.

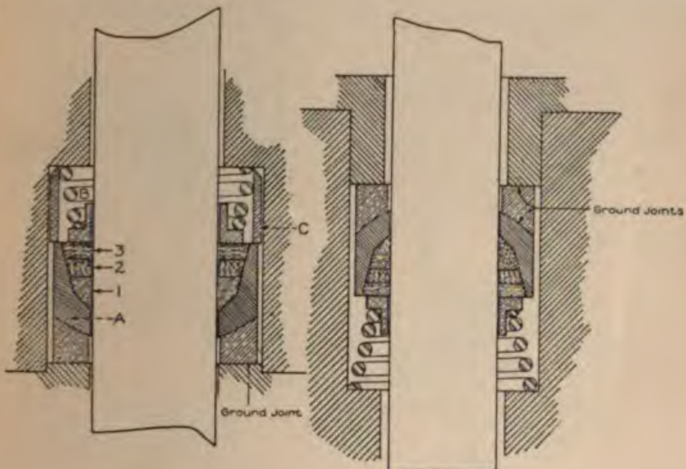


FIG. 104.—Single junior piston rod packings.

The piston is screwed on the rod against a taper shoulder and is secured by a lock nut in the face of which are radial grooves; a split pin through the rod lies in one of the grooves in the nut preventing the nut from working loose.

The high-pressure piston (Fig. 103) is of steel; it is screwed to the rod and riveted.

The piston rod is of forged mild steel. It is threaded at the lower end and is screwed into the cross-head and locked by a spanner jam nut.

[NOTE 21.—**To assemble the pistons,** place the high pressure piston packing in place and bind with cord or wire; take off the low pressure piston and put the high pressure piston in the cylinder; as the packing passes

the end of the high pressure cylinder the cord or wire will be pushed off (if not, remove it); then place the intermediate cylinder head on the rod and secure it in position; pack the stuffing box and screw down the gland tight. Place the low pressure piston packing in place and secure it as was done with the high pressure packing; place the piston on the rod, removing the cord or wire.]

The L. P. piston packing (Fig. 103) consists of four cast-iron arcs, overlapping at the ends and made steam tight by brass tongues, one of which is riveted to each arc. The packing is held against the cylinder wall by flat steel springs, one of which is fastened to each arc.

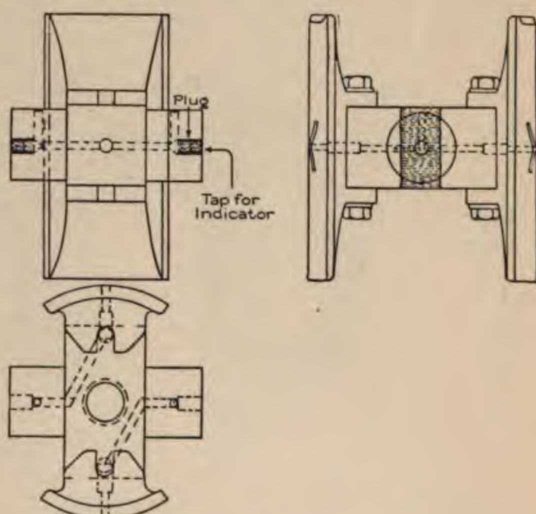


FIG. 105.—Cross-head.

The H. P. piston packing is of the same construction as that for the L. P., except that there are but three arcs.

The piston-rod packings are known as the Single Junior type, and are shown in Fig. 104.

The H. P. packing (left hand of figure) consists of a vibrating cup, *A*, receiving the babbitt metal packing rings 1, 2, and 3. These rings are in halves and should break joints in assembly. The vibrating cup has a spherical bearing so that the packing will follow the rod in any position. The steam pressure forces the packing down in the cup and against the piston rod, thereby preventing the leakage of steam. The coil spring *B* assists the

pressure, at the same time holding the packing in place and preventing the rings from following the rod at the moment of reversal. The vibrating cup is held in position by the space ring *C*.

The L. P. packing (right hand of figure), is similar to the H. P. packing, except that no space ring is used.

Whenever this packing is overhauled care should be taken that it is free of grit before reassembly.

The throttle valve is of the 90-degree angle Lunkenheimer type, looking up.

The cross-head (Fig. 105) consists of a rectangular steel

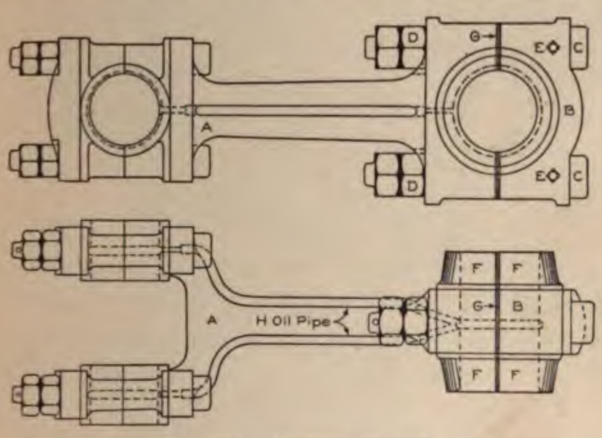


FIG. 106.—Connecting rod.

block with two cylindrical projecting parts which form the wrist pins. Curved composition slippers are fastened to the cross-head by tap bolts; wear is taken up by inserting liners between the cross-head and the slippers.

The method of conveying oil from the pin to the guide is shown in the illustration.

The connecting rod (Fig. 106) consists of a forged steel body, *A*, forked at the upper end for receiving the wrist-pin brasses, each set of which is held in place by two through bolts with double nuts and split pins. Wear is taken up by filing the faces of the brasses.

The lower end of the rod terminates in a stud to which the crank-pin box is secured by a steel cap *B* and two bolts *CC*, with

double nuts *DD*, and split pins. The set screws *EE* are for the purpose of preventing the turning of the bolts *CC*. The crank-pin bearing consists of a cylindrical cast-steel shell *F* in halves, having two small flanges which engage the connecting rod and prevent lateral motion of the shell; turning of the shell is prevented by through bolts and liners. The interior of the shell, which comes in contact with the shaft is babbitted, and wear can be taken up by removing the fiber liners *G*. It is important that the boxes in this, as well as in the top bearing, be always tight, in order to avoid the leakage of oil, which must be forced from the lower bearing through the pipes *H* to the wrist pin and the cross-head guide.

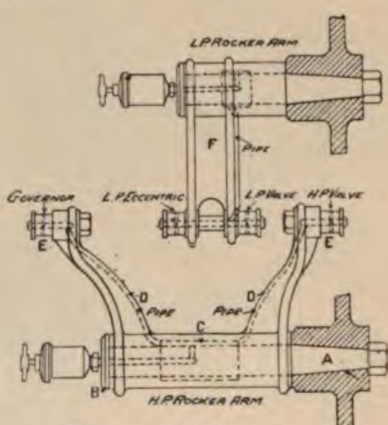


FIG. 107.—Rocker arms.

The valve motion is accomplished through the valve stems by the two **rocker arms** shown in Fig. 107. The lower one in the figure is actuated by the governor connecting rod, and gives motion to the high-pressure valve; the upper is actuated by the l. p. eccentric and gives motion to the low-pressure valve. Each rocker arm bears on its stud *A* which passes through the column and is secured by a nut. The washer *B* at the end of the stud *A* is tapped for a screw grease cup which forces the lubricant to chamber *C* in the rocker arm, from which it is further forced through pipes *DD* to the journals *EE*.

The valve stems are threaded at the lower end and screwed into a small cross-head (Fig. 108), to which they are secured by lock nuts; the central portion of this cross-head is square and

the ends are cylindrical, forming bearings with the link, *B;* the the bearing caps *CC* for the pins are each secured by two bolts screwed in the bottom half of the link and locked by a nut;

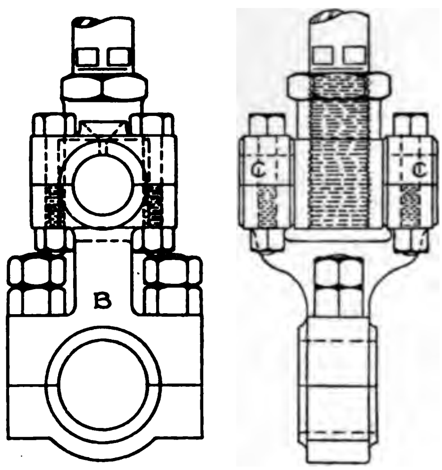


FIG. 108.—Valve stems and links.

wear is taken up by filing off the faces of the caps. The lower end of the links contains a bearing, similar in construction, which receives a pin fixed in the rocker arm; here also wear is taken up by filing the cap faces.

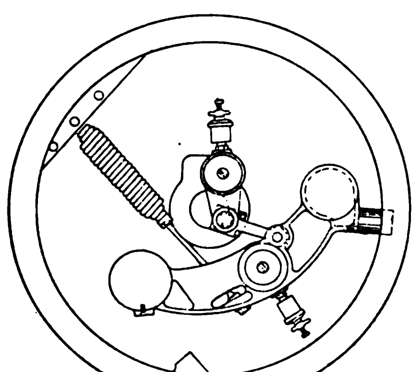


FIG. 109.—Governor, tandem-compound.

An indicator reducing motion is attached to each engine. By removing the nut on the end of the inboard rocker arm stud, a

bracket may be attached and the nut can be replaced; a stud projecting from this bracket forms the fulcrum of the pendulum; the opposite end of the pendulum is slotted and receives the end of a stud, which can be screwed into the cross-head bearing when the oil cup is removed.

The governor (Fig. 109) is contained in a heavy fly-wheel keyed on the end of the shaft. The method of control of speed is similar to that described for the 100 k. w. type.

The ideal grease cup (Fig. 110, *A*) is provided with a leather-packed plunger against which rests a coiled spring. The spring and plunger are conveniently controlled by a thumb-nut; turn this to the right until the plunger is raised to the top of the cup, unscrew the cover and fill the cup with grease, replace the cover and adjust the pressure on the grease by the thumb-nut, allowing

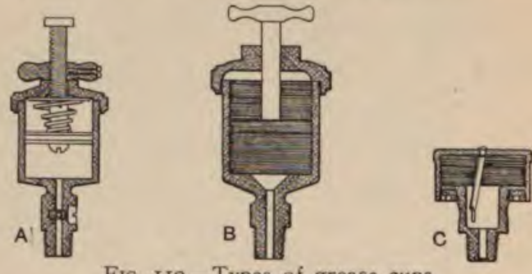


FIG. 110.—Types of grease cups.

the spring to press on the plunger forcing out the grease. The rate of feed may be regulated by the set screw in the lower part of the cup in which there is a hole in line with the slot.

The "marine" grease cup, No. 1 (Fig. 110, *B*), is used for forcing the lubricant to the rocker arms and the valve-motion pins.

The "tiger" grease cup (Fig. 110, *C*) is sometimes used on the engine and is different in operation from the two just described. By screwing down the cap the lubricant is forced to the bearing; a leather washer prevents the grease from leaking out of the cup and can be easily replaced when worn out; a spring locking arrangement, the projection of which engages at each turn, prevents the cap from jarring off, and also cuts and loosens the grease.

All of these types of grease cups are for use with Albany grease.

The system of forced lubrication used is shown in Fig. 111, and with the various parts already explained (see also description for the 100 k. w. type).

Features of the Generator.

The dynamo used with the form G type of generating set has been known as the M. P. form A, but is now included in the general letter of the type (G); the sizes are 16, 24, 32, and 50 k. w.

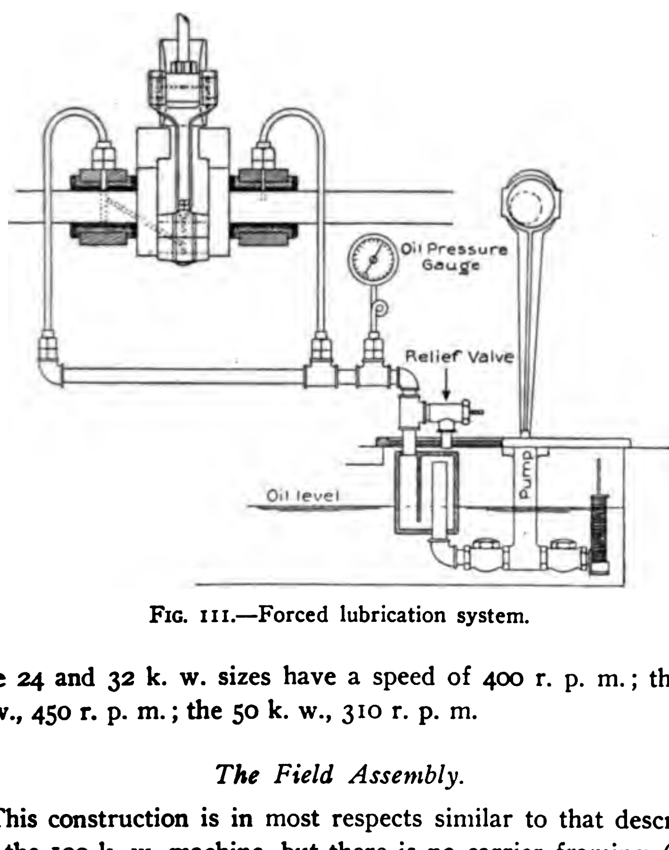


FIG. 111.—Forced lubrication system.

The 24 and 32 k. w. sizes have a speed of 400 r. p. m.; the 16 k. w., 450 r. p. m.; the 50 k. w., 310 r. p. m.

The Field Assembly.

This construction is in most respects similar to that described for the 100 k. w. machine, but there is no carrier framing (Fig. 101), a hand-rocker system being used with the machine instead.

The field winding has no ventilation spaces, otherwise it is as before described in other than dimensional and winding details.

The Armature.

The 50 k. w. armature shown in section in Fig. 112 is a typical example of the series-wound, wave-wound, barrel-wound construction; the series-wound feature is also termed a two-circuit winding.

The essential features in construction of the armature are the following:

The coupling is not forged with the shaft, but drives by a key in the key-way *B*.

The legs of the spider are joined together at the commutator end by a cast-iron disc *K*, which extends up to the line of the inner surface of the slots; between each of these legs are spaces

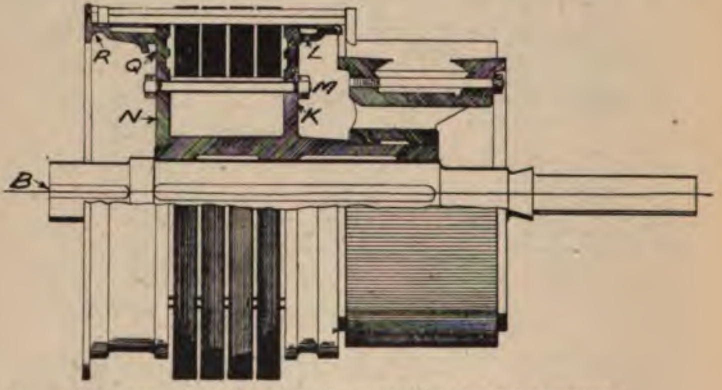


FIG. 112.—Details of 50 k. w. series-wound armature.

to admit of the circulation of air. The disc is flanged outwardly at *L* to support the extension of the windings which project beyond the slots; in this disc, and intermediate between the legs, are six bolts, *M*, which draw in place a similar disc, or follower, *N*, which supports the back end of the core and draws the sections of the core together; the follower *N* is further provided with a dove-tailed groove, *O*, in which metallic lead may be inserted for balancing, and there is an extension of its flange, *R*, higher than the windings, to throw off oil by centrifugal force, and prevent it from flowing back on the armature.

The armature core is made up in four sections, separated by space blocks for five ventilation spaces; in the 32 k. w. size there are but three sections, and in all other sizes, two sections.

The armature winding for a 32 k. w. size consists of 77 or 108 coils (there are two designs), each coil being made of two bars of copper 0.15 inch by 0.444 inch in multiple, no insulation being placed between the bars. There are two windings for each slot and top sticks of ash are driven to secure the winding in the slot.

The number of commutator bars is the same as the number of slots, which is a difference as compared with the multiple-wound generator.

The brush gear is shown in Fig. 113.

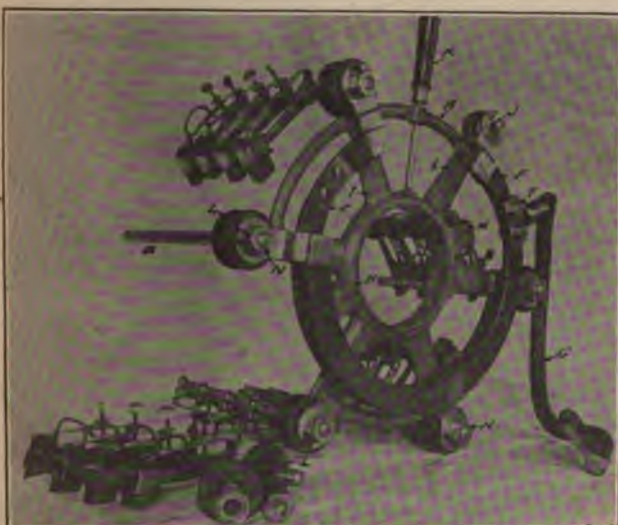


FIG. 113.—Brush gear design.

The rocker, *A,* is of cast iron and divided to fit over a flanged collar on the outboard (ring-oiler) bearing; it is loosely secured around the collar by the flange joints *H*. The arms *I*, one for each pole of the dynamo, are slotted in jaws at the end *J* for the studs. At the top and bottom are two cast masses for the clamp handle *K;* the upper mass is bored without tapping, while the lower is tapped, the clamp handle *K* can thus secure the rocker in any desired position by screwing down by the handle; the clamp handle serves also for turning the rocker around the collar of the bearing.

The brush holder stud, *B*, is a rod of steel which carries at the rocker end the insulator and securing nut. The insulator *L* consists of two discs of hard rubber or white fiber, which are separated from each other by a small bush of the same material as the discs (the bush is the cylinder forming the insulation between the stud and the jaw in the rocker end). A brass washer is placed outside the outer disc, and the brush connector clamped between the washer and the nut *N* on the stud end; the stud is thus in electrical connection with the brush connector *F*, but is insulated from the rocker.

The two **brush connectors,** *F*, are copper bars bent to the curve of the rocker to connect brushes of the *same polarity;* they are held in place by the nut *N* on the stud. To prevent accidental short-circuiting the connectors are covered with tape. The brush leads *G* are bolted to the connectors at *T* and to the insulated block on the dynamo frame; there is but one block on a board on the frame of machines smaller than 100 k. w., which serves for all leads.

The brush holder differs in construction from that shown in Fig. 97, but this latter type is now generally used on all types of machines, and the holder of Fig. 113 is falling into disuse.

Generating Sets for Torpedo-Boat Destroyers and Torpedo Boats—General Electric Company.

The generating set types for these uses are designed in two sizes, 5 and 2½ k. w.; the former is known as the M. P. 6-5-700 type, and the latter as the M. P. 6-2½-800. Both are similar in construction.

Especial Features of the M. P. 6-5-700 (80 Volts).

The set complete is shown in Fig. 114.

The Engine.—The engine is of the single-cylinder, vertical, double-acting, open, wrought-steel frame type, and has a speed of 700 r. p. m. at full load with 100 pounds steam pressure. The working parts of the engine are enclosed in a sheet-iron case (not shown) made in two pieces, which are removable.

The part of the bed plate extending out to take the dynamo frame consists of two cored arms, faced at the top for the dynamo frame flanges; in later types this construction has given way to the usual pillow block bearing.

The crank shaft is made from one solid piece of forged steel. The crank is machined out. Cast-iron counterbalance weights are cast on the crank webs over the cap bolts opposite the crank pins; a flanged coupling is shrunk and keyed on to the armature end for connecting with the flange on the armature shaft, a cored boss fits a corresponding recess in the armature

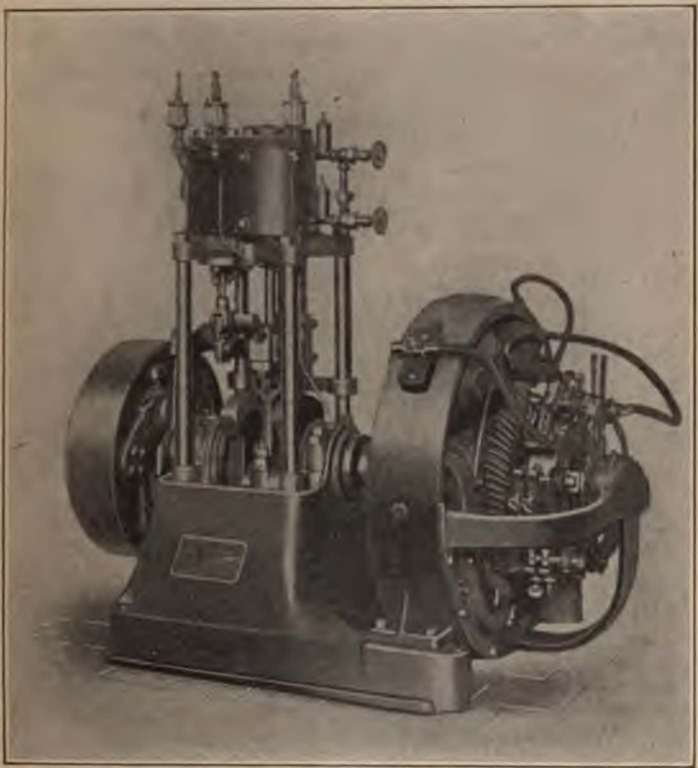


FIG. 114.—General Electric Company's M. P. 6-5-700, generating set.

shaft flange to assist in aligning. The shaft has a diameter of 1¾ inches at the main bearing and 1¾ inches at the crank-pin bearing. The crank-pin bearing is lubricated by oil from the main bearing next the generator, the oil being carried by centrifugal force through an oil hole extending through the shaft, crank, and crank pin.

The cylinder, valve chest, and stuffing box for the piston-rod packing are made of cast iron in one piece (Fig. 115). The diameter of the cylinder is 4 inches and the length of the stroke is 4 inches. The steam pipe is screwed into the boss, *A*, in the center of the steam chest. The exhaust pipe is at the back of the engine and at the bottom of the valve chest; it is screwed into the boss, *B*, and serves as a drain for the cylinder. The cylinder is tapped in front, both at the bottom and top (*C*) for indicator attachments; it is also fitted with a combined drain and relief valve, the drain consisting of a ¼-inch pipe and the relief valve

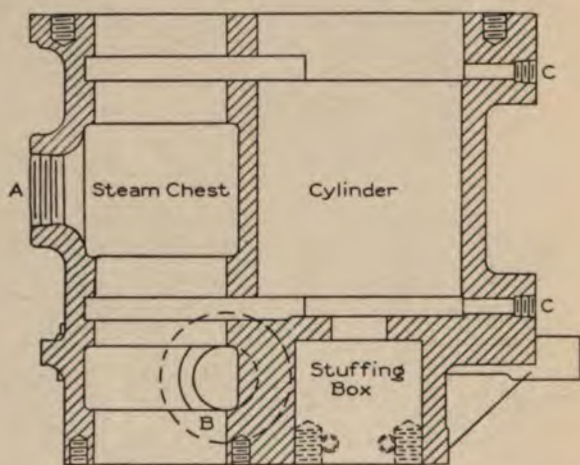


FIG. 115.—Cylinder casting.

of the usual pop valve. The cylinder head and the valve bonnet are made of one piece of cast iron and are fastened to the cylinder by nine ½-inch studs.

The valve is of the balanced piston type. The travel is controlled by the governor and varies between 1½ inches and ⅝ inch, varying the cut-off in the cylinder between ¾ and zero, depending on the load; the exhaust from the top of the cylinder passes through the center of the valve. At the upper end of the valve there are four webs connecting the inner circumference of the valve with a central boss to which the valve stem is attached. The steam lap is ⅜ inch, and the exhaust lap zero, top and bottom.

The valve stem consists of a mild steel rod ½ inch in diameter, the upper end of which passes through the boss at the upper end of the valve, and is secured by double nuts on each side of the boss; when set the nuts are locked hard together leaving the valve free to turn but without any play. Soft packing of good quality should be used in the valve-stem stuffing box.

The piston consists of a cast-iron disc, containing a cylindrical groove, which receives the piston packing ring. The piston fits on the taper on the piston rod, and is secured by a ⅝-inch nut on

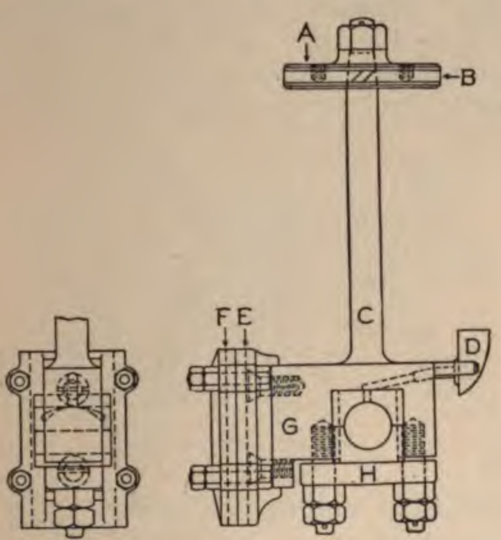


FIG. 116.—Piston rod and cross-head.

the upper side, in which is inserted the usual split pin to prevent the unscrewing of the nut. The piston packing is a single cast-iron ring overlapping at the ends and forming an angle joint.

The piston rod, *C,* and the **cross-head,** *G* (Fig. 116), are in one forging of mild steel. The cross-head shoe, *E,* is of gun metal and is fastened to the cross-head by two ½-inch flat-head screws, which are relieved of side pressure by the webs of the shoe. The cross-head is held against the guide bar by the clamp, *F,* which is connected to the shoe by four through bolts; the proper distance between the shoe and the clamp being maintained by ribs on the shoe and on the clamp. Wear may be taken up by

filing these ribs, but the filing must be done parallel to the wearing surfaces. The cross-head is slotted to receive the wrist-pin bearing which is made of gun metal, and is held in place by a cap, *H*, and two studs with double nuts. The bearing should be so adjusted that when the brasses are hard together the wrist pin will move easily but without play. Oil reaches the bearing from the oil cup, *D*, through a hole in the top of the bearing.

The rocker arm, *B* (Fig. 117), is a steel casting keyed to the rock shaft, *C*, which transmits motion to the rocker arm, *D*, with pin, *E*, which is attached to the governor connecting rod. The rocker arm is supported by a cast saddle, *F*, which is attached to the columns at the side of the engine and fixed in position by two through bolts. The lower end of the valve stem is threaded and

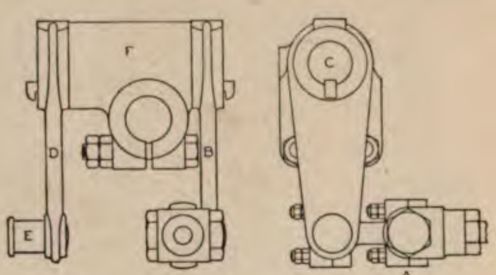


FIG. 117.—Rocker arm.

screwed tightly into an eye which connects the valve with the rocker arm by a link.

The cross-head guide bar consists of a steel bar, the upper end of which is fastened to the cylinder by two fillister head screws; the lower end is attached in the same way to a cross-bar through whose bosses pass the back columns of the engine. The cross-bar is secured to the column by set screws. Oil reaches the cross-head shoe through an oil hole extending down from the top of the guide bar sufficiently to be always covered by the shoe.

The connecting rod is a mild steel forging, forked at the upper end to receive the wrist pin. The wrist pin is of hardened steel, 1¼ inches in diameter, ground true and shrunk in the connecting rod. The lower end of the connecting rod contains the crank-pin bearing; this bearing is cast-steel shell lined with babbitt metal and is in two parts, separated by liners, and secured to the

connecting rod by two ⅝-inch through bolts and cap. When adjusted the connecting rod should move easily, without play. Wear is taken up by filing or taking out the liners.

The governor is a modification of the Rites design and is shown in Fig. 118. It is placed inside of the fly-wheel and on its outer side. The fly-wheel, *A*, is keyed to the shaft and carries the governor parts, consisting of: a weight *B*, pivoted at *C*; an eccentric *D*, with counter-weight *E*; a coiled spring *F*, taking by a knife-edge on teeth at the upper side of the weight; and a link *G*, connecting the weight to the end of the bell crank of the counter-weight.

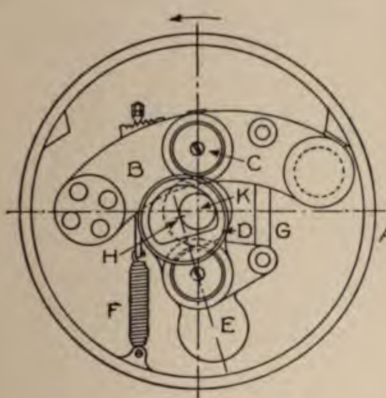


FIG. 118.—Governor.

The operation of the governor is as follows: The eccentric strap, which transmits motion from the governor to the valve, is connected to the eccentric *D*; the travel of the valve, therefore, depends upon the distance of *H* from the crank *K*. If the speed increases, the weight *B* is immediately thrown by centrifugal force toward the perimeter of *A*, decreasing the distance between *H* and *K* and shutting off steam from the cylinder; if the speed becomes too great the minimum distance between *H* and *K* is reached and practically all steam is shut off. Control of speed is effected by the tension of the spring, increasing, the tension increases the speed and *vice versa*. The same effect will respectively be produced by moving the knife-edge suspension away from or towards the fulcrum *C*.

The generator, shown in Fig. 114, is of the general type explained in connection with the form G generating set, and generates 5 kilowatts, at 80 volts, and 700 r. p. m.

The series winding consists of 10½ turns of sheet copper 0.025 inch by 2.75 inches, the turns insulated from each other by 0.008-inch linen of sufficient width to overlap the edges. The weight of each coil is approximately 3.3 pounds. Resistance, cold, 0.0015 ohm. The series lead consists of copper strips 0.025 inch by 0.875 inch, two in multiple formed around a 2-way connector having a 5/16-inch hole.

In each coil of the **shunt winding** are 750 turns of No. 15 B. & S. G. single cotton-covered wire, the weight of which is about 12 pounds. Resistance, cold, 3.7 ohms. The shunt leads consist of strip copper 0.025 inch by 0.4375 inch, two in multiple, formed around a 2-way connector having a 3/16-inch hole.

The series and shunt coils are separated by two thicknesses of oiled asbestos each 0.015-inch thick, and two layers of varnished cambric each 0.0125-inch thick. The insulation between the series lead and the shunt winding consists of a pad composed of three thicknesses of varnished cambric and two of red paper arranged alternately, making a total thickness of approximately 0.06 inch. For the purpose of making a straight winding on all sides of the spool two wooden sections are placed on each side of the series lead. These are used merely as a filler and are as thick as the lead plus the insulation between the lead and the shunt winding.

The armature winding consists of 71 coils, each coil made up of 2 turns of No. 12 B. & S. G. double cotton-covered twin wire, arranged two in multiple with the ends brought out to form connections.

The brush gear is similar to that described under the form G, the brushes used being about ¾-inch thick.

The M. P. 6-2½-800 Set.

This generating set is similar to but simpler than the M. P. 6-5-700 just described. The 80-volt set complete with sheet-iron case removed is shown in Fig. 119.

The piston rod and the cross-head are in one forging of mild steel. The cross-head shoe is of gun metal, and is fastened to the

cross-head by two 5/16-inch flat-head screws which are relieved from side pressure by the webs of the shoe. The cross-head is held against the guide bar by a clamp, which is connected to the slide by four through bolts; the proper distance between the shoe and the clamp is maintained by four distance pieces through which the bolts pass. Wear is taken up by filing the ends of the distance pieces but care must be taken that the pieces are all of the

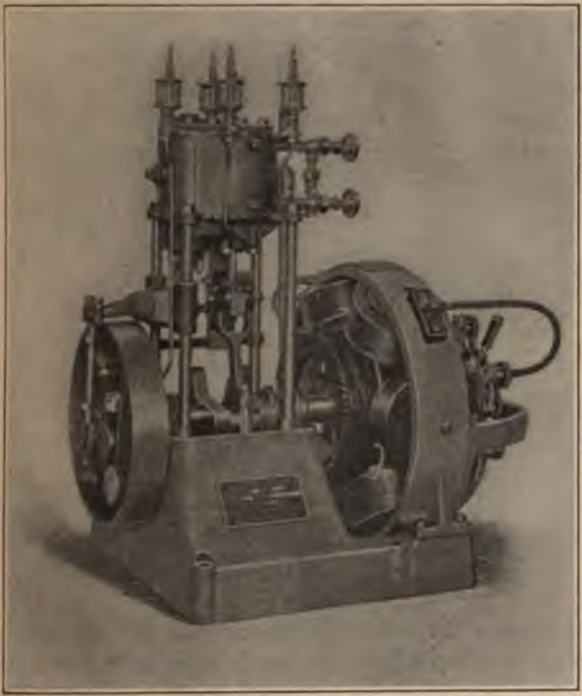


FIG. 119.—General Electric Company's M. P. 6-2½-800, generating set.

same length. The cross-head is drilled to receive the wrist-pin bearing, which is made of gun metal, and is held in place by a flange on one end of the bearing, and a key and a set screw on the under side. The bearing should be so adjusted that when the set screw is tight and the nut locked, the wrist pin will move easily without play. Oil reaches the bearing from an oil cup through a hole in the top of the bearing.

The rocker arm is a casting of elliptical cross-section, on one

end of which is a spherical steel bearing to which is attached the governor connecting rod. The rocker arm is supported by a cast-iron saddle, which is attached to the columns at the side of the engine and fixed in position by set screws. The lower end of the valve stem is threaded and screwed tightly into an eye which connects the valve with the rocker arm by double links.

The connecting rod is a mild steel forging, forked at one end to receive a wrist pin, which is of hardened steel $\frac{7}{8}$ inch in diameter, ground true after hardening. Each end of the pin is tapped and threaded for a $\frac{1}{4}$-inch pipe tap, and contains four slots; inserting a plug in each end of the wrist pin will separate the sections of the pin formed by the slots and hold the pin in place; the pin may be removed by taking out the plugs and slid-

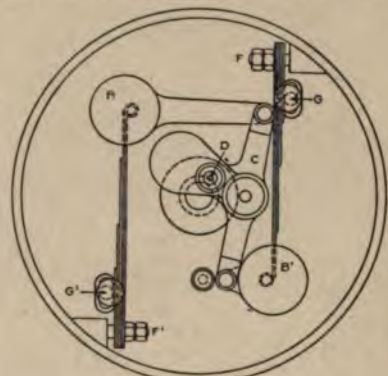


FIG. 120.—Governor.

ing the pin from the rod. The lower part of the connecting rod contains the crank-pin bearing, the two parts of which are bolted together by two $\frac{3}{8}$-inch through bolts with lock nuts. The bearing is of gun metal lined with babbitt and is $1\frac{3}{8}$ inches in diameter. When adjusted the connecting rod should move easily without play; wear is taken up by filing the caps.

The governor is a modification of the Rites design and is shown in Fig. 120. It is placed inside of the fly-wheel or pulley and on its upper side. The pulley *A* is keyed to the shaft and carries the governor parts, consisting of two weights *B* and *B'* connected to the opposite ends of the lever *C*, on which is the pin *D* operating the valve. The centrifugal force of the weights is opposed by the leaf springs which are connected to the fly-

wheel by the studs *F* and *F'* with double nuts, and which fulcrum on *G* and *G'*. The springs are held in place by flanges on the ends of the fulcrums.

The operation of the governor is as follows: The governor connecting rod which transmits the motion from the governor to the valve, is connected to *D*; the travel of the valve, therefore, depends upon the distance of *D* from the center of *A*. If the speed increases the weights *B* and *B'* are immediately thrown by centrifugal force toward the perimeter of *A*, decreasing the distance of *D* from the center of *A* and shutting off steam from the cylinder; when *D* and the center of *A* nearly coincide practically all steam is shut off.

The Generator.—The dynamo is of the general type as indicated in connection with the form G generating set, and generates 2½ kilowatts at 80 volts and 800 r. p. m.

The series winding consists of 22½ turns of No. 7 B. & S. G. double cotton-covered wire arranged two in multiple. The weight of each coil is approximately 3 pounds; resistance, cold, 0.0068 ohm. The series lead consists of copper strips 0.225 inch by 0.875 inch, two in multiple, to which is attached a 2-way connector.

In each coil of the **shunt winding** are 650 turns of No. 16 B. & S. G. single cotton-covered wire, the weight of which is about 7 pounds. Resistance, cold, 2.14 ohms. The shunt leads are of strip copper 0.025 inch by 0.4375 inch, two in multiple, with 2-way brass connector attached. The shunt winding is outside over the series.

The armature winding consists of 61 coils, each coil made up of 4 turns of No. 12 B. & S. G. double cotton-covered wire, arranged two in multiple, the ends brought out to form connections. The total weight of insulated wire for the winding is 20.5 pounds.

The brush gear is the same as in the 5 k. w. generator; there is but one brush per stud.

Form A—General Electric Company.

The general idea of this type of generating set is to obtain a simple, single cylinder, commercial type of generating set which is strong and light and of few parts. It has a single-cylinder

engine combining many of the advantages of the form G tandem-compound, and the dynamos have been wound for 80, 110, and 125 volts.

The type has been mainly bought for auxiliaries, for torpedo boats, or for temporary sets of gunboats, and consists essentially of two varieties. The later type has, in addition to other differences, a six-pole dynamo; the earlier, a dynamo of four poles; this distinction, however, merges as the six-pole type is four-pole in sizes of 4 k. w. and 2½ k. w. in the general classification.

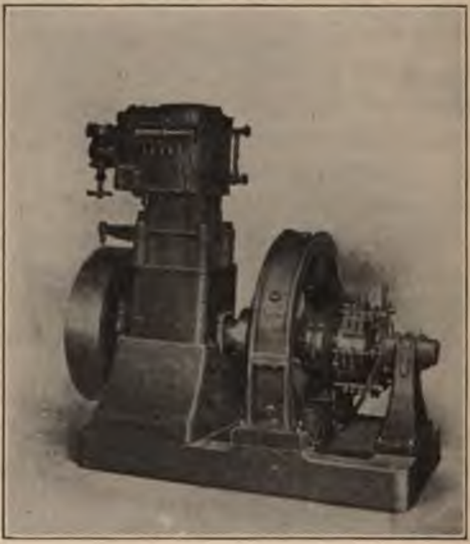


FIG. 121.—General Electric Company's Form D generating set.

When the 2½ k. w. is wound for 80 volts it is rated down to 2 k. w. The set shown in Fig. 121 is the 30 k. w. size, or M. P. 6-30-305.

The Engine.—The engine is of the vertical, inverted, reciprocating, simple, condensing and non-condensing, double-acting, direct-connected type, with a single cylinder.

The cylinder and valve-chest casting is in one with the casting carrying the rock shaft and the cross-head guide; this latter casting rests on a second which forms a casing and the base for the cross-head guide. Both castings are secured to the pedestal of the bed-plate by stud bolts passed through holes drilled

through bosses or flanges. Access to the interior of the casing is had through a door, not shown, on the back of the casing. The cylinder is cased with Russian iron, the space between the casing and the cylinder being filled with a non-conducting material.

The piston rod and cross-head are forged in one piece from machine steel; the cross-head shoes are of phosphor bronze; they have large wearing surfaces and are similar to those used for the form G, tandem-compound. Adjustment is not often required; good adjustment can be obtained by placing a thin sheet of paper or metal between the cross-head and shoe. The wrist-pin bearing is fitted with adjustable phosphor bronze boxes.

The piston is of solid cast iron with eccentric cast-iron packing rings set in two grooves; it is secured to the rod by a taper end and nut as described for preceding types.

The connecting rod is of forged machine steel in one piece, forked at the cross-head end, and having the usual stub end at the crank pin. The wrist pin is made of steel, hardened, ground true, and shrunk into the connecting rod. The crank-pin box is of cast steel lined with babbitt, with removable liners which are divided for taking up wear; the boxes can be rebabbitted.

The valve is of the solid piston type and similar to that used for the high-pressure valve in the compound engines.

The governor is of the Rites dumb-bell pattern; it is capable of changing the cut-off from ¾ to zero.

Lubrication.—All moving parts, with the exception of the governor, are lubricated by gravity, drop, sight-feed lubrication fed by a tank attached to the cylinder casing, as shown. Grease cups are used for lubricating the governor.

The Generator.—The dynamo, in all its parts, is practically the same as that used with the form G, a slight but not important change being made in the method of winding the armature.

4-Pole Type.—The 4-pole type is practically the same as the 6-pole, just described; exceptions are as follows:

Engine.—The **cylinder** and **valve-chest castings** rest on four cast columns through which the studs from the pedestal pass, thus leaving the engine open instead of enclosed. The rocker stud is secured to one of the columns. A cast casing is formed at the top of the columns for carrying the cross-head guides.

The Governor.—The weight is controlled by a spring which

is attached to the weight by a knife-edge whose position can be adjusted on a series of teeth. A counterpoise (of the valve-gear weights) carries the journal for the governor eccentric and is actuated by a short link secured to the weight and at the point of the counterpoise near the governor eccentric journal. The action is the same as the Rites patterns.

Generating Sets of the Union Iron Works.

The generating sets made by the Union Iron Works, San Francisco, California, are, in 50, 32, and 24 k. w. sizes and are, in general, of the type described in the following 50 k. w. example, which is installed in the U. S. battleship *Ohio*. A cross-section is shown in Fig. 122.

The Engine.—The engine is vertical, inverted, reciprocating, cross-compound, condensing and non-condensing, double-acting, variable-expansion in high-pressure cylinder, open frame, with accessory enclosing shields, direct-connected.

There are two **shaft bearings**; the seats are formed by semi-circular recesses machined in the bed-plate. The boxes are of composition with dove-tails cast in to secure the Parson's white metal lining; the bearing will come around to the top of the shaft and be in position to be lifted off for examination or repair.

The crank shaft has two cranks at an angle of 180°. The coupling flange is forged solid with the shaft as are also the crank pins; the latter are afterwards drilled for oil holes, the oil being supplied to the crank bearings by means of centrifugal oilers attached to the sides of the cranks.

The fly-wheel, which also contains the governor, is overhung on the part of the shaft extending beyond the outer crank-shaft bearing and at the opposite end of the shaft from the armature.

The engine frame has one column which supports both cylinders and carries the cross-head guides. The two steel stanchions serve to support the front ends of the cylinder casting and, in general, brace and strengthen the engine. A casing of sheet steel is fitted to each engine, forming an oil enclosure; it has a swinging door by which practically all the working parts of the engine can be viewed. No gaskets are provided to make the doors air-tight, as forced lubrication is not used.

The cylinder and valve chest are in one iron casting; the

center line of the valve chests and cylinders is in one line, the valve chests being at the ends. There are no bushings or liners for the bores of the cylinders. The high-pressure valve chest

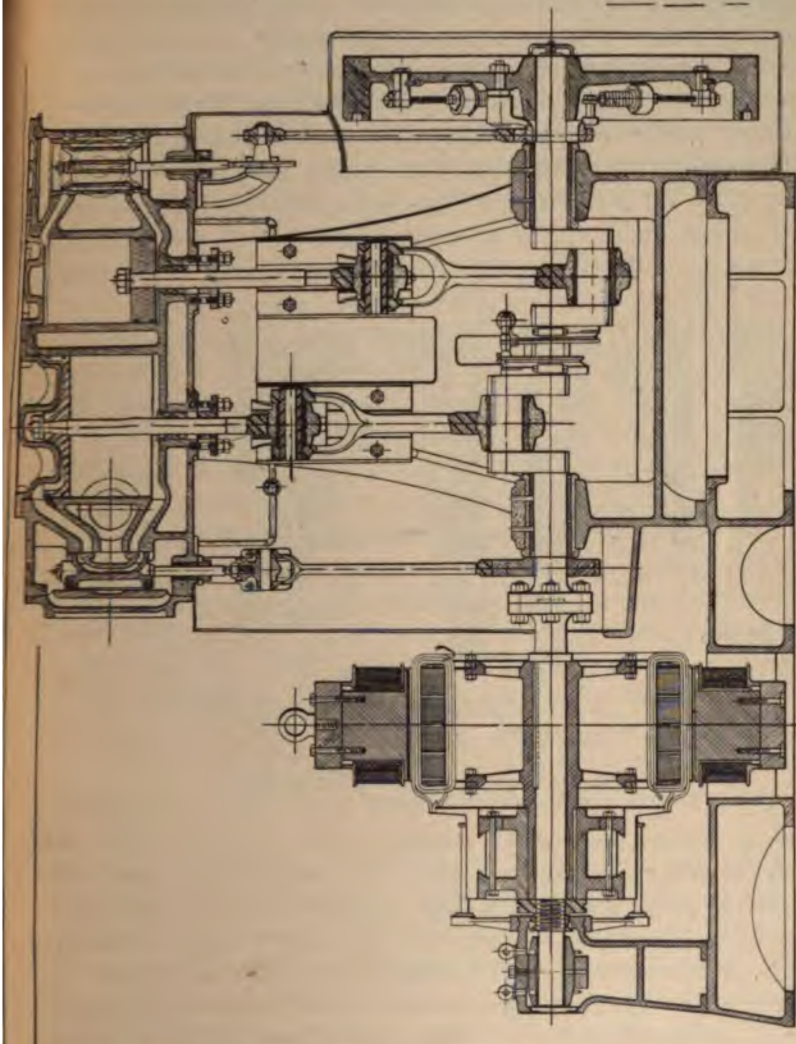


FIG. 122.—Union Iron Works 100 k. w. generating set.

has a bushing of cast iron. The lower heads are cast in place; an opening, sufficient only for the stuffing boxes, is fitted and consequently the pistons and high-pressure valve must be removed from the top.

The piston-rod and valve-rod packings are metallic, of the Katzenstein type; those on the high-pressure and low-pressure piston rods are similar and of the "sectional self-acting" form, and are shown in Fig. 123. In the lower cylinder heads is a large bushing, *A*, which forms a guide for the piston rod and a surface against which the packing rings are placed. Each ring has a serial number; the rings are placed in position in the sequence of their numbers. Rings No. 1, B, No. 3, D, and No. 5, F, are of bronze and cut in segments; these form conical surfaces forcing into place the packing rings No. 2, C, and No. 4, E, made of

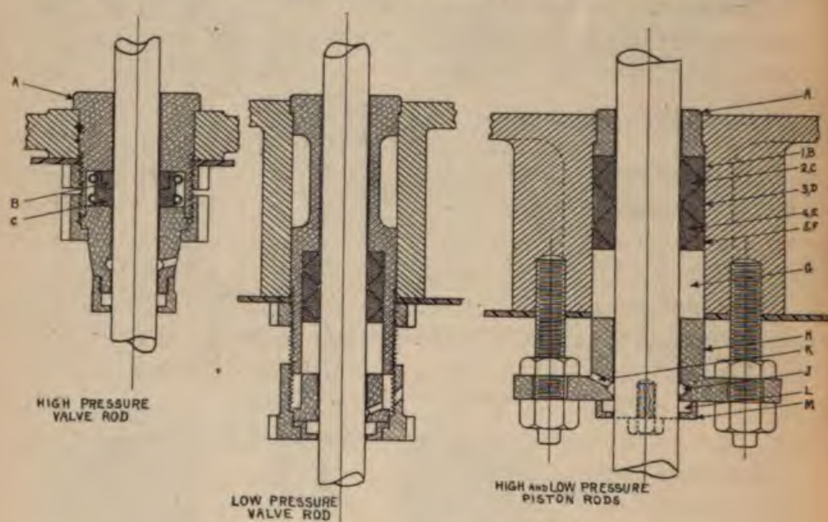


FIG. 123.—Katzenstein metallic packing.

special anti-friction metal. Rings No. 2, C, and No. 4, E, are also cut in segments, in the placing, the joints are staggered with reference to the segments of rings No. 1, B, No. 3, D, and No. 5, F. It will be noted that rings No. 1, B, and No. 3, D, and No. 5, E, do not come in contact with the rod, but leave spaces between their edges in which the water of condensation may collect. In the space, *G*, below the rings, fibrous packing is placed, increasing the elasticity of the contact of the rings and facilitating lubrication. The gland, *H*, is of bronze and guides the piston rods at their lower ends. A groove turned in at *J* is drilled with a drain hole, *K*. Below this is an auxiliary stuffing space, *L*, in

which a turn of fibrous packing is placed, and retained by the bronze gland, *M*.

The packing of the low-pressure valve rod is of similar type to that of the piston rods. The packing on the high-pressure valve rod is of the "automatic cup" form.

The steam and exhaust openings are both at the rear side.

The upper cylinder heads, high and low pressure, are separate.

The upper head of the high-pressure valve chest is a round iron casting with a hollow boss which forms a guide for the upper end of the high-pressure valve stem.

The cover of the low-pressure valve chest is a rectangular iron casting with a boss projecting outside. This boss is hollow and contains a spiral steel spring pressing a plate of composition, which rides on the back of the low-pressure valve, against the stud end and keeping the valve in its seat.

The high-pressure piston is a solid cast-iron disc with shallow recesses on each side at the nut and rod. The center is bored on a taper for the rod. In the periphery two grooves for the piston rings are cut; these rings are of cast-iron and of the spring type.

The high-pressure valve is an iron casting of the piston type, single-ported, balanced by being surrounded by steam, hollow, taking steam at neck and exhausting through the center to the ends. There are no facilities for keeping the valve tight except by replacing the valve chest liner and turning down the valve.

The low-pressure valve is an iron casting of the flat type with the supplementary port of the Allen design, giving a steam opening double that of the usual form. The travel is constant; the pressure is unbalanced. A pressure plate keeps the valve against its seat.

The lubrication of the engine is by drip feed and oil cups. The main supply is from a tank on the forward side of the cylinders, from which tubes lead to the high-pressure eccentric, outer crank shaft bearing, high-pressure cross-head slide, high-pressure cross-head (two), high-pressure crank pin, low-pressure cross-head (two), low-pressure cross-head slide, inner crank-shaft bearing, and low-pressure eccentric strap. The tubes for the high-pressure and low-pressure cranks drip into bronze rings which are attached to the inner ends of the cranks. The oil is thrown by centrifugal action to the outer edge of the recess in the

rings and through holes in the pins to the bearing surfaces. The tubes for the eccentric straps drop into cups at the forked end of the eccentric rods; the oil is led through a tube alongside of the rod to the upper half of the eccentric strap.

A brass **oil guard**, attached to the lower end of the low-pressure valve chest and the engine bed-plate, prevents any oil or drip from the engine from reaching the generator; another guard of sheet steel shields the fly-wheel from oil and the drip of the drains.

A system of **drain piping** terminating in a common outlet is fitted to the high-pressure and low-pressure valve chests and to both ends of the high-pressure and low-pressure cylinders.

Relief vales are fitted to each end of the high-pressure and low-pressure cylinders, on the rear side, and are independent of the drain piping.

Indicator Gear.—On the centrifugal cup of the crank shaft, nearest the center line of the engine, eccentrics are embodied for surfaces on which rollers, on the levers of the indicator motion, are kept in contact by spiral springs at the pivot of the levers. These pivots are mounted on lugs at the back of the engine frame. A detent and lever admit of lifting the lever from contact with the slide. The short ends of the levers have a hole to which the cords are attached. The indicators are on the rear side of the cylinders.

The governor (Fig. 124) is of the centrifugal shaft type, swinging the high-pressure eccentric in an arc, and by altering the angular advance and throw produces those changes in admission, expansion, exhaust, and compression, which are required for the varying conditions of load. The parts of the governor are mounted on the engine side (inside) of the fly-wheel, and consist of a double set of weights, arms, springs, stops, and adjustments. Being double, the governor as a whole is balanced at all times; both sets are connected by a link, attached to the weight arms, and to the kite-shaped casting of which the high-pressure eccentric forms a part. The adjustments are made by varying the position of the weights on the arms, the spring tension, the position of the outer attachment of the springs, and the throw of the arms.

To increase the speed the weight may be shifted away from

the spring, or decreased in weight; or the spring may have less tension, or be moved at the outer end towards the rim. For close regulation the outer point of suspension of the springs should be moved towards the rim; this will decrease the speed; to compensate for this either the tension may be increased or the weights be moved farther from the springs. Too close regulation tends to cause hunting, but can be overcome by moving the outer point of suspension of the springs away from the rim. To compensate for the increase of speed either decrease the tension or move the weights towards the springs.

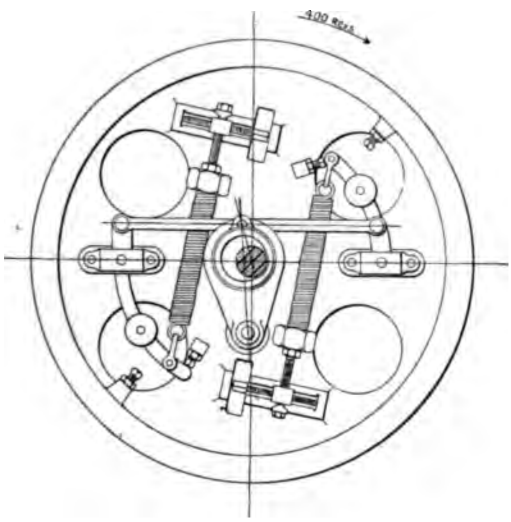


FIG. 124.—Governor.

The Generator (Fig. 122).—**The field frame** is of circular shape and rectangular section, horizontally divided, and having machined surfaces for cores. The two halves are secured together with lugs and bolts and the pole cores are secured in position by means of bolts passing through the frame.

The pole cores are fitted with separable, cast-steel shoes, secured in place with screw bolts.

The spools carrying the **field winding** are mounted on the pole cores. They are made of 1/16-inch asbestos and two layers of varnished bristol board. After this insulation is in position the series field conductor is wound, consisting of 4½ turns per

spool of two No. 13 Brown and Sharp gauge copper strips, in parallel; each strip is 5 inches wide. The insulation between the turns of the series conductor consists of 26-mil. (8-oz.) oiled duck. On top of the series conductor an insulation consisting of oiled bristol board and flexible mica is next placed and the shunt is then wound. This winding consists of 516 turns per spool of No. 9 B. & S. gauge, single cotton-covered magnet wire, the insulation of which is soaked in an insulating varnish prior to winding. The finished winding is varnished with a black insulating compound.

The armature is of the Pacinnoti-Gramme type.

The spider is made of cast iron and has six arms. It has an extension upon which the commutator is mounted and secured in place by a steel feather 10½ inches long. A lock nut setting up against the end of the spider and commutator clamps the former securely in place. The lock nut also secures the commutator in place against a shoulder on the extension of the spider on which it is mounted.

The armature **core-discs** are made in sections, each section subtending an angle of 60 degrees. Six sections are required to form a complete disc. The discs are mounted on the driving rods so that the joints are staggered 30 degrees apart, about 570 complete discs being required for the completed core. The discs are insulated from each other by thin coatings of japan.

The armature body has three cast brass ventilators spaced about 3 inches apart. They extend entirely around the armature and consist each of a ring made in web-bed form with 108 projections on each side which separate the discs sufficiently to permit of the formation of the same number of ventilating openings. The armature has two end flanges; the discs being insulated therefrom by discs of ⅛-inch fiber, slotted similarly to the core-discs.

There are 108 slots in the armature. Each slot is 1 1/16-inch deep and 7/16-inch wide; tapering to the full width of 7/16 inch for the first 5/32 inch of the total depth. For the remainder of its depth the slot forms a regular parallelogram. A T-shaped tooth is thus formed, the overhang of which serves to retain in place the hardwood wedge which, in turn, holds the armature conductor in position in the slot.

The armature winding consists of three turns per slot, five in

parallel, of .040 by .340 double cotton-covered copper of rectangular section. Before winding the conductors in place they are treated with an insulating varnish with which the insulation is thoroughly soaked.

The system of armature winding employed is that commonly known as the "simplex ring," having parallel, singly-reentrant grouping of conductors. The armature is hand-wound and the connecting pitch is one bar. No equalizer rings are used in this type of armature. The ends of the coils are soldered directly into the commutator bar lugs, there are 108 connections, the same as the number of coils and lugs.

The commutator consists of 108 cold-rolled copper bars with riveted and soldered lugs. No cross connections are employed.

There are the same number of **sets of brushes** as there are poles for the magnetic circuit, viz.: six; three positive and three negative. The brushes are of carbon, 1 inch by 2 inches by 4 inches in size. As the bars are each .536-inch wide the brushes, which are 1-inch thick, do not quite cover two bars. They feed in arcs of 4¾-inch radius.

The brush gear is mounted on a rocker arm which is, in turn mounted upon an extension on the pillow block. The rocker arm has six arms, each of which carries a brush stud upon which six brush holders are mounted; the total number of holders being 36. The brush holder cables, or leads, consist each of three "extra flexible" cables of about 300,000 circular mils cross-section each.

Each generator is provided with a **headboard** carrying a circuit breaker of the "ITE," laminated wedge, edgewise, double-pole type.

Generating Sets of the B. F. Sturtevant Company.

Until recently the generating sets supplied by this company were of the 5 k. w. size for torpedo-boat destroyers. The later designs include 100 k. w. and 50 k. w. sizes.

The Engine.—A cross-sectional view of the 100 k. w. engine is shown in Fig. 125; it has also been installed in conjunction with dynamos of other than the Sturtevant manufacture.

The cylinders are 10 inches and 18 inches diameter by 10-inch stroke.

The steam pressure is 150 pounds normal, the engine being designed to work at a normal vacuum of 25 inches or on atmospheric exhaust.

The construction of the engine embodies the same general features which contribute to the strength, durability, and satisfactory operation of the form H of the General Electric Com-

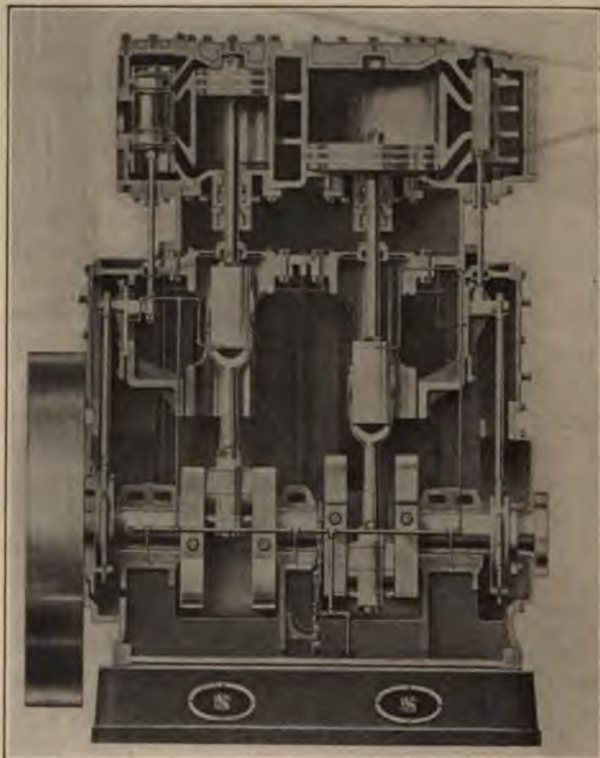


FIG. 125.—B. F. Sturtevant Company's Engine, 100 k. w.

pany already described in detail. The salient features of the particular design are noted as follows:

The cylinders and valve chests are cast with an annular recess into which non-conducting material is packed to prevent radiation of heat from the heads.

The high-pressure piston valve is fitted with two snap rings and one guide ring on each end.

The pressure plate of the **low-pressure valve** is not self-adjusting.

The high and low-pressure cross-head shoes are double-surfaced, and curved to fit against the inner bored surfaces of the cross-head guide. This latter is bored circularly with a long opening on the inner sides where most accessible and a smaller opening on the other sides; a flanged ring at the upper end is bolted to the underside of the guard plate and are removable from below as required for truing up.

FIG. 126.—Outside view of governor.

The high-pressure eccentric is mounted on a pin extending through the fly and governor wheel; the arrangement resembling the device used in the Union Iron Works engine.

The upper halves of the **main bearings** are cast hollow.

The forced lubrication system is similar in general details to systems already described; the pipe connections are shown in Fig. 125.

The governor is of the Rites "dumb-bell" type and is mounted on the outside of the fly-wheel as shown in Fig. 126. This particular variety of weight in governors of the type is discussed in the Notes on Generating Sets farther on in this text, and from which it only differs in that an eccentric is actuated by a pin

through the fly-wheel to the dumb-bell weight instead of by a connecting rod to a rocker arm as in the form G, General Electric Company; this change in device permits the use of a weight at greater radius to actuate an eccentric, rod, and strap within the enclosed engine casing, and the spring is more accessible for adjustment. The outside weight design has the advantage of accessibility, but has the disadvantage of less thorough lubrication of its journal.

The Generator.—The dynamo is, in general details, much the same as the 100 k. w. already described, and is of the 8-pole construction.

The pole shoes are separable from the field cores, with the **series coil** next to the shoes.

The shunt coil is wound on a single spool with a dividing air space running the length of the coil at the center of the winding.

FIG. 127.—Brush-holder.

The armature is of the multiple-wound, drum-wound, slotted-core type.

The brush holder is shown in Fig. 127, and is a characteristic feature of Sturtevant dynamos and motors; the brush is pressed down by a phosphor bronze spring, while an extra spring action is given to the adjusting screw by securing its end in another spring attached to the bottom of the brush holder.

The brushes are wide in comparison with their width, requiring fewer brushes per stud. When set, the brushes on one stud stagger with the next succeeding, to give even wear to the commutator surface.

Generating Set for Torpedo-Boat Destroyers.

The Sturtevant design for a 25 k. w. generating set is shown in Fig. 128 and differs mainly in the governor; for torpedo-boat use the set is of 5 k. w. capacity, generating 80 volts at 62.5 amperes and 500 r. p. m.

The overall dimensions in inches are: length, $49\frac{1}{8}$; width, $27\frac{3}{8}$; height, $27\frac{1}{2}$. The weight is 1275 pounds.

The Engine.—The engine is of the vertical, simple, double, enclosed type. The designed steam pressure is 100 pounds rated, but is capable of a variation from 120 to 80 pounds, with a

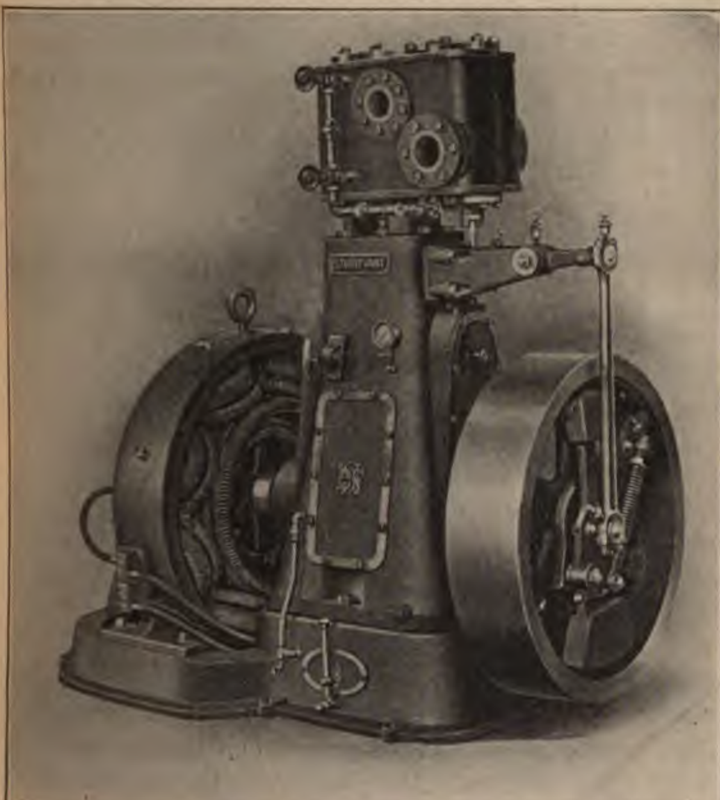


FIG. 128.—Sturtevant Company's 25 k. w. generating set.

vacuum of 25 inches or atmospheric exhaust. The cylinder dimensions are $3\frac{1}{2}$-inch by $3\frac{1}{2}$-inch bore with $2\frac{1}{2}$-inch stroke. The steam and exhaust pipes are both $1\frac{1}{2}$ inches in diameter.

The governor, shown in Fig. 129, is of the Shepherd design which, while having points of similarity to the Rites' type, embodies some especial features of construction and action. The

governor wheel *A* is the fly-wheel of the engine; the eccentric *B* to which the eccentric rod and strap are attached, is shown in the cross-sectional view. The eccentric is carried by the weight arm *C* to which it is attached by two fillister head screws. The weight arm is attached to the governor wheel off its center, so that the eccentric has a pivotal motion which affects the travel of the valve and also the lead of the valve at different points of cut-off. The main weight *D* is cast on the weight arm at the left-hand end; the right-hand end is bored for a cross pin which connects with the auxiliary weight *E*. The governor spring *F* is attached to the auxiliary weight by a hooked end which encircles a pin in the weight; there are three adjusting holes in the

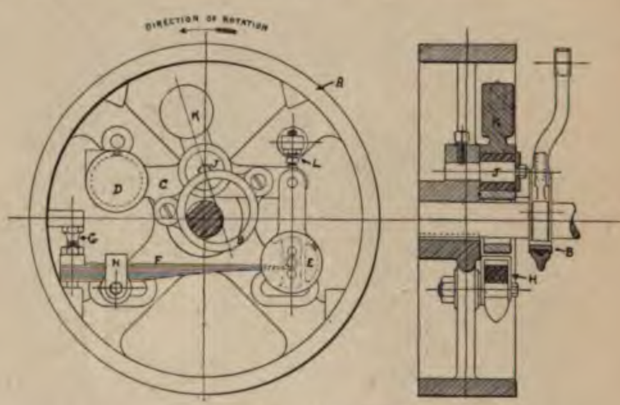


FIG. 129.—Governor.

weight for this pin. The spring is attached to the governor wheel by a stud *G*. A nut on the upper side of the spring affords means of adjusting the tension to balance the weights for the required speed. The direction of the movement of the outer end of the spring under compression is such as to describe substantially the same arc as the main weight *D*. The position of the fulcrum of the spring *H* is adjustable, and the strength of the spring, that is, the ratio of the increase in tension, is so varied as to practically balance the weights at all positions of their movement. The auxiliary weight *E* is pivoted to the end of the weight arm, rather than made rigid with it, in order that the centrifugal force acting upon the arm may be added to the force acting on the main weight. If it were rigid and had a

pivotal action around the stud *J* the effect would tend to oppose the force acting on the main weight. The link attaching the auxiliary weight *E* is of such a length as to bring the auxiliary weight diametrically opposite the main weight *D* that they may balance each other; the arms of the weight arm *C* are also balanced in the same way. The weight of the eccentric *B* is balanced by the weight *K*. The stop at *L* prevents the inside of the eccentric from striking the shaft and limits the maximum travel of the valve.

The two weights, *D* and *E*, are hollow and partly filled with lead shot. The speed can be changed by adding or removing shot; add shot to both to *decrease* speed; remove shot from both to *increase* speed. A slight change in speed can also be made by changing the spring tension at *G*, but much change will affect the regulation. A great change in speed, by changing the weight of shot in the hollow weights *D* and *E*, will sometimes necessitate a readjustment of the spring to maintain the same degree of regulation; this is due to the fact that adding or deducting weight at one point alters the center of gyration of the system.

If the governor does not keep the desired speed under load, the spring tension should be increased at *G*. Increasing the spring tension will increase the speed; to counteract this, either add shot to the weights *D* and *E* or move the spring fulcrum *farther* away from the center of the wheel. The spring tension can be changed by the nut on the adjusting stud *G*; also by changing the pin to another hole in the balance weight *E*. If the engine should run faster under no load than with load, and to a greater speed than is desired, *decrease* the spring tension and regain the speed thereby lost by deducting shot, or by moving the spring fulcrum *H* *toward* the center of the wheel.

The Generator.—The dynamo (Fig. 128) is designated as the special 1-100-M. P.-8 type. The voltage is 80 at 500 r. p. m., with an output of 5 k. w.

There are eight poles.

The field coils are made up without spools. The series coil is inside and consists of 11 turns of copper strip, 2½ inches by 0.024 inch. The shunt coils are wound outside of the series and consist of 12½ pounds each of No. 15 B. & S. G., D. C. C. C. wire, Over the windings are four thicknesses of tape.

To ensure water-proofing, the coils, after winding, are soaked one hour in an insulating varnish, then drained one hour and baked for 24 hours at 120° to 180° F.; then the tape is wrapped on and varnished.

The Forbes' Engine.

W. D. Forbes & Company are engine builders and do not manufacture generators; engines of the type have been received in combination with Crocker-Wheeler, Bullock, and Thresher dynamos.

The engine design has several individual features differing from types heretofore described.

The 100 k. w. size, shown in cross-section in Fig. 130, is designed for 150 pounds of steam, at 25 inches vacuum or for atmospheric exhaust. The cylinders are 10 inches and 20 inches and 10-inch stroke.

The enclosing frame is comparatively light, and is intended more as an oil guard than for engine construction, the cylinders and valve chests being supported by four stanchions within the frame, set up in bed-plate by nuts and extending up through the top of the casing where they are secured by nuts and washer; these stanchions carry the cross-head guides for the piston rods and the rock-shaft bearings. The enclosing frame supports the valve-stem guides.

The piston-rod packings are of the Katzenstein type (Fig. 123).

The piston rod and cross-head are in one forging and in one with the cross-head is the cross-head side having a T-shaped section in its extension, from the cross-head to top of the "T" running under the guides; these latter embrace the top of the "T" and control the cross-head motion to the center line. Wear is taken up by liners back of the guide face.

The connecting rod is forked, securing with the ordinary stub end, and is comparatively short.

The high-pressure valve is between the cylinders and is actuated by an eccentric secured to the shaft.

The high-pressure and low-pressure cylinders are reversed as compared with most other constructions, *the high-pressure cylinder being next to the dynamo. The governor controls the*

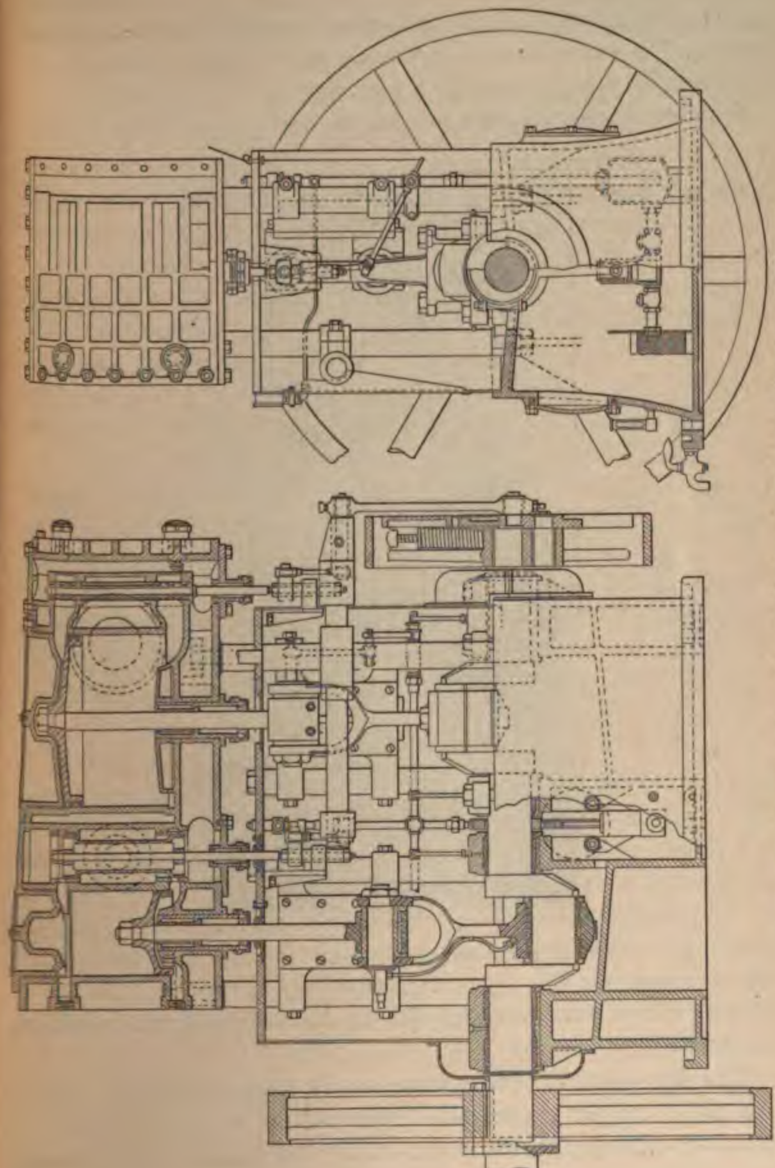


FIG. 130.—Cross-section W. D. Forbes & Company Engine, 100 k. w.

L. P. valve in this engine and not the H. P. valve as is the case.

The rock-shaft extends through the casing from the gc end and is supported by journals secured to the stanchio receives its motion through a governor connecting rod an municates its motion to a link on the valve stem of the lo

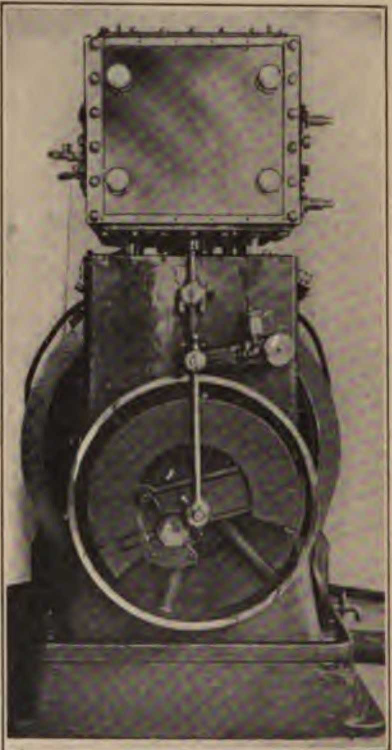


Fig. 131.—Governor, 100 k. w. engine.

sure valve, the stem working in a square box guide on the of the casing.

The fly-wheel is between the engine and the dynamo assembled on the engine shaft; the hub is used as a fl attach to the flange of the armature shaft, the radial keys being fitted in slot-ways in both the fly-wheel hub coupling flanges; the crank-shaft bearing next the dyn

therefore made long to support the overhung weight of the fly-wheel, the weight of both fly-wheel and armature being supported by this bearing and the pillow block bearing at the end of the armature shaft.

Governor.—There are two types of governor used with the Forbes' engine, both constructed on the Rites' design.

The type used with the 100 k. w. engine is shown in Fig. 131. The weight embraces the greater part of a circle and is attached to a cross-arm pivoted as shown. The spring controls the centrifugal motion of the weight in the usual way. The fulcrum of the spring is adjustable in a slot. The action and adjustments are the same as for other governors built on the Rites' design.

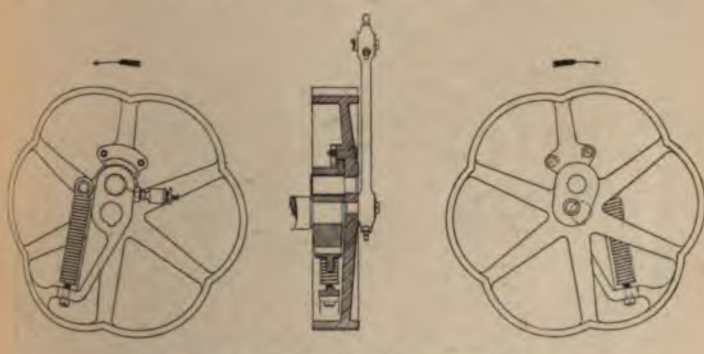


Fig. 132.—Governor for 24 k. w. and below.

The type used with smaller engine designs is shown in Fig. 132. It is a modification of the Corliss type of the Rites' design. The governor standing part is an iron casting keyed to the shaft. At one side of the shaft is an extension which is bushed to form the bearing for a stud extending from the governor weight, and in the opposite direction is an extension which forms the outer point of attachment of the governor spring. The governor weight is a cam-shaped iron casting. The parts of the wheel face between the arms (or spokes) are arched out to reduce shrinkage strains, and to reduce, by a multiplied fluttering, the optical effect of the governor's eccentric rotation. To one of the six arms is attached a stud which forms the inner point of attachment of the governor spring. The eccentric pin is of machine steel and extends outwardly from the hub of the governor weight.

The governor weight retaining plate is a composition casting which is secured by two fillister head machine screws to two extensions of one of the governor arms and engages with a projection at the governor standing part to keep the governor in position longitudinally on the stud. When any "sticking" occurs with this type of governor, it will usually be found in a too tight setting up of the cap nut that secures the weight.

The outboard, or dynamo end, bearing, is a straight sleeve bearing.

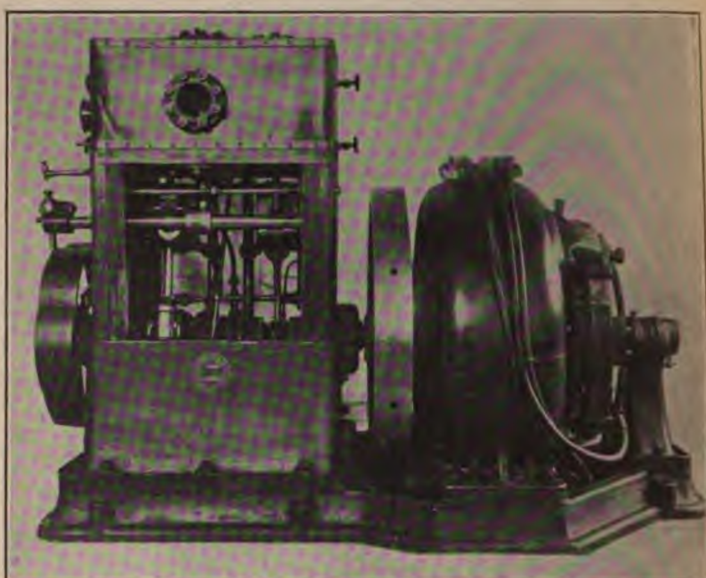


FIG. 133.—Crocker-Wheeler 16 k. w. generator (Forbes Engine).

[NOTE 22.—The Forbes' Company supply the bed-plate and pillow block bearing for combinations for which they furnish the engine. This rule is general where the dynamo and engine are not constructed by the same corporation.]

The Crocker-Wheeler Generator.

A 16 k. w. generating set combining the Forbes' engine and Crocker-Wheeler dynamo is shown in Fig. 133; the same combination has been supplied in the 100 k. w. size.

The generator shown is of the modern form of multi-polar-field, drum-wound, slotted-core armature.

The 210 **core discs** are of .022-inch sheet steel with sixteen 3/64-inch discs at the ends of the core divisions; 50 paper discs .003-inch thick separate the discs to reduce Foucault currents.

The **armature winding** consists of 76 coils of alternately 2-turn and 3-turn coils in 76 slots.

The **conductor** is one No. 6 double cotton-covered, with 10 wires to each slot.

The **connections** are six-circuit to 152 commutator bars.

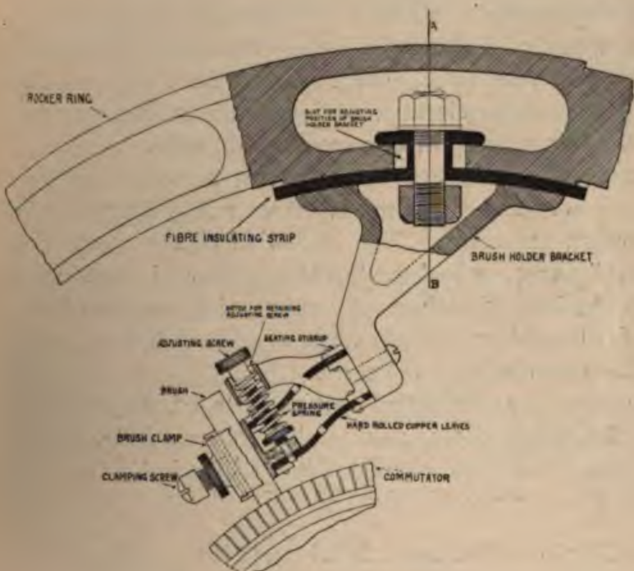


FIG. 134.—Brush rigging.

The insulation on the coil is 1-inch linen tape, and in the slots two .012-inch press-board and two .008-inch Empire cloth.

The bands are ½-inch wide and of No. 20 phosphor bronze wire.

The commutator bars are of rolled copper separated by .035-inch micanite. The tails of the bars are of two copper strips riveted in a slot in the end of the bar and also riveted together.

The brush-holders, shown in Fig. 134, are of the radial type, the tension being provided by a steel-wire spring in compression. The brush-holders are bolted to brackets which extend radially inward from the cast-iron rocker ring. Slots in the rocker ring

admit of varying the angle between the various brushes to adapt the brush position to any variations in magnetic balance of the armature circuits. The holder is attached to the rocker ring through two laminated flat springs of .05-inch copper.

The brushes are of carbon and are clamped in place. They may be lifted from contact with the commutator by raising the entire brush-holder until the shoulder of the adjusting screw is outside of the hole, and then pushing the adjusting screw back until the shoulder overlaps the edge.

The field frame is circular in shape and divided at the center. At the points of division flanges are turned inwardly to take the two bolts in each side. The edges of the frame are turned in towards the center slightly, adding to the stiffness of the frame and affording extra protection to the field coils.

The field spools are tin cylinders surrounding the cores; they have a brass head at the armature end and a glavanized iron end toward the frame. The insulation of the cylinder is "P" and "B" paper, and of the heads a washer of 3/32-inch fiber.

The winding of each spool consists of 750 turns of No. 10 D. C. C. for the shunt, and 8½ turns of ¾-inch by .015-inch copper strip, 13 in multiple for the series.

The shunt on the series coil consists of, approximately, 24 loops of German silver, 4 in parallel, ⅞-inch wide, which are to be adjusted to suit the characteristics of the individual generator.

CHAPTER VII.

MOTORS.

General Considerations as to Types in Use.

In 1871 the electrical energy supplied to a ship consisted of one or two small Farmer's series dynamos, whose armature was revolved by a hand crank and whose output did not exceed 100 or 150 watts, an amount of energy which is now-a-days consumed by a single 32 c. p. lamp. The *Alabama* class and the *Iowa* are supplied with an output of 96,000 watts; the *Brooklyn*, with 150,-000 watts; the *Kearsarge*, with 350,000 watts; and the *Connecticut*, with 400,000 watts, or 711 horsepower at 33 per cent overload.

The growing output is mainly due to the increasing demands for electrical drive, which consumes fully 80 per cent of the total power allotted in the generators. The ease and facility of maintaining and repairing electric leads; the objectionable heat of long lines of steam piping; the annoying leaks of hydraulic apparatus; the bulk and weight of pneumatic machines; the avoidance of the complications incident to several different systems of drive within the same ship; the injurious or distracting effect on the personnel of a compartment in case of accident to, or the cutting of, pipe lines in battle; the satisfactory efficiency and economy of electric drive as compared with other systems, and its flexible adaptability to power use in general, have practically caused the adoption of electricity as the actuating agent for all power purposes outside of the engine and fire-rooms and their immediate connections; in these compartments steam drive is still in general use. There are two exceptions as yet to the general application of electric drive for ship auxiliaries as compared with steam; they are for actuating the steering engine and the capstan or windlass. The peculiar shocks and stresses to which the rudder and anchor hoist are often subjected have not thus far been demonstrated to be as readily controllable by electrical methods, as by the cushioning effect of steam or air; electrical

Service.	No.	Make.	Type.	Form.	Winding.	H. P.	Volts.	Amperes.	Controller.	No. of Rheo-stats.	Type of Rheostat.	Circuit Breaker and Brake.
MOTORS FOR MOTOR GENERATORS.												
Turret Turning, 12-in.......	2	Gen. Elec. Co.	C. B. G. 4-25-100	B	Compound	35	125	200	....	....	....	....
Turret Turning, 8-in.... ..	4	Gen. Elec. Co.	C. B. G. 4-25-100	B	Compound	20	125	120	....	....	....	....
Gun Elevating, 12 in........	4	Crocker-Wheeler .	G. E...	....	Shunt	8	125	43	....	....	....	....
Gun Elevating, 8-in........	8	Northern Elec. Co.	....	....	Shunt	5	125	28.1	....	....	....	....
Wireless Telegraph.........	1	Crocker-Wheeler .	....	....	Compound	5	125	37.50	....	....	....	....
Telephone.....	1	Holtzer-Cabot Co.	E.	....	Shunt	¼	125	2.35	....	....	....	....
MOTOR FOR DYNAMOTOR.												
Interior Communication...	1	Crocker-Wheeler .	D. M....	....	Shunt	....	125-20	4	....	....	....	....
MOTORS.												
Turret Turning, 12-in.......	4	Gen. Elec. Co.	C. B.-25	G	Shunt	35	125	240	Gen. Elec. Co. P-10-A.	4	Gen. Elec. Co. Special.	Brake Type C. Circuit Breaker, Gen. Elec. Co., Type M. Q.
Turret Turning, 8-in.......	8	Gen. Elec. Co.	C. B.-32	A-1 ..	Shunt	15	125	105	Gen. Elec. Co. P-10-A.	8	Gen. Elec. Co. Special.	Brake Type C. Circuit Breaker, Gen. Elec. Co., Type M. Q.
Ammunition Hoists, 12-in..	4	Gen. Elec. Co.	C. B.-25	B-9 ..	Shunt	55	120	390	Gen. Elec. Co. B-44-A.	36	Gen. Elec. Co. P. R. Form 80.	Brake E. D. 111. Brake Rheostat P. A. Form A.
Ammunition Hoists, 8-in..	8	Gen. Elec. Co.	C. B.-38	B ..	Shunt	17	120	101	Gen. Elec. Co. B-28-E.	24	Gen. Elec. Co. P. R. Form 80.	Brake E. D. 111. Brake Rheostat Type M. C.

Am'tion Hoists, Chain, 7-in.	12	Gen. Elec. Co.	C. B.-27	F-3	Shunt	3	125	23	....	....	....	....
Am'tion Hoists, Chain, 8-in.	14	Gen. Elec. Co.	C. B.-27	F-3	Shunt	3	125	22	....	....	....	....
Ammunition Hoists, Whip.	6	Gen. Elec. Co.	C. B.-33	B	Shunt	3	125	24	Gen. Elec. Co. B-34-B.	6	Gen. Elec. Co. P. C.	Circuit Breaker, Gen. Elec. Co., Type M. Q.—30/60
Ammunition Conveyor	4	Gen. Elec. Co.	C. B.-27	B	Shunt	4	125	30	....	....	....	....
Gun Elevating, 12-in.	4	Gen. Elec. Co.	C. B.-17	A-25	Shunt	8	125	44	Gen. Elec. Co. Special Cont. Rheostat.	4	....	....
Gun Elevating, 8-in.	8	Gen. Elec. Co.	C. B.-15	K-18	Shunt	5	125	28	Gen. Elec. Co. Special Cont. Rheostat.	8	....	....
Gun Ramming, 12-in.	4	Gen. Elec. Co.	C. B.-27	S-22	Series	10	120	74	Gen. Elec. Co. R-95-B.	4	Gen. Elec. Co. P. C.	Circuit Breaker, Gen. Elec. Co., M. Q.
Gun Ramming, 8-in.	8	Gen. Elec. Co.	C. B.-29	A-1	Series	3½	120	21	Gen. Elec. Co. R 95-A.	8	Gen. Elec. Co. P. C.	Circuit Breaker, Gen. Elec. Co., M. Q.
Boat Crane, Hoisting	2	Gen. Elec. Co.	C. B.-24	C	Series	50	125	340	Gen. Elec. Co. Hoisting and Turning.	16	Gen. Elec. Co. P. R.	Brake E. D. 108. Gen. Elec. Co., Circuit Breaker, Form Q, Amp. 500-1000.
Boat Crane, Rotating	2	Gen. Elec. Co.	C. B.-25	G	Series	30	125	210	Combined R-62-A.	12	Gen. Elec. Co. P. R.	Gen. Elec. Co. Circuit Breaker, Form Q, Amp. 500.
Deck Winches	6	Thresher Elec. Co.	M	....	Compound	25	125	175	Thresher Elec. Co. W. P. Drum.	6	Cast Iron Grid Type.	Circuit Breaker. Cutter Co.
Power Doors and Hatches.	47	Long Arm Co.	....	....	Compound	1	125	8.8	Long Arm Co. Special.	....	....	....

Service.	No.	Make.	Type.	Form.	Winding.	H. P.	Volts.	Amperes.	Controller.	No. of Rheostats.	Type of Rheostat.	Circuit Breaker and Brake.
					MOTORS FOR VENTILATION.							
80-in. Steel-Plate Fan	2	Holtzer-Cabot Co.	E.-20		Shunt	12	125	81				
60-in. " "	5	Holtzer-Cabot Co.	E.-7½		Shunt	6.3	125	44				
55-in. " "	2	Holtzer-Cabot Co.	E.-7½		Shunt	5.8	125	40				
50-in. " "	2	Holtzer-Cabot Co.	E.-7½		Shunt	4.6	125	32				
45-in. " "	6	Holtzer-Cabot Co.	E.-5		Shunt	3.75	125	27				
40-in. " "	2	Holtzer-Cabot Co.	E.-3		Shunt	2.6	125	18				
35-in. " "	1	Holtzer-Cabot Co.	E.-3		Shunt	2.2	125	16.1				
30-in. " "	1	Holtzer-Cabot Co.	E.-2		Shunt	1.65	125	12.1				
No. 6 Monogram Exhaust Fan.	2	Holtzer-Cabot Co.	E.-3		Shunt	2.7	125	20.5				
No. 4 " " "	8	Holtzer-Cabot Co.	E.-2		Shunt	1.1	125	8.2				
No. 2 " " "	2	Holtzer-Cabot Co.	E.-1		Shunt	.75	125	6.				
¼-H. P. Portable Fan	6 2	Sturtevant Holtzer-Cabot Co.	F. B M.	C	Shunt	1/4	125	1.6 2.38				
1/6-H. P. Fan	8	Western Elec. Co.			Shunt	1/6	125	1.				

SELF-CONTAINED MOTORS ON WORKSHOP TOOLS.

26-in. x 48-in. Extension Gap Lathe.	1	Westinghouse Elec. & Mfg. Co.	No. 4. Type S.	.....	Shunt	7½	125	61.5	....	....	....	....
16-in. Shaper...........	1	Westinghouse Elec. & Mfg. Co.	No. 6. Type S.	....	Shunt	5	125	36.5	....	....	....	....
Universal Milling Machine.	1	Westinghouse Elec. & Mfg. Co.	No. 2. Type S.	....	Shunt	2	125	17	....	....	....	....
Emery Grinder.............	1	Stow Mfg. Co., Binghamton, N.Y.	....	....	Shunt	2	125	17	....	....	....	....
23½-in. Drill Press	1	J. Clark, Jr., & Co.	....	....	Shunt	1	125	12	....	....	....	....
14-in. Lathe.........	1	Westinghouse Elec. & Mfg. Co.	No. 2. Type S.	....	Shunt	1	125	9.2	....	....	....	....
Sensitive Drill Press.......	1	J. Clark, Jr., & Co.	....	....	Shunt	1/4	125	2	....	....	....	....

MISCELLANEOUS MOTORS.

Dough Mixer...............	1	Gen. Elec. Co.	2-3	A	Shunt	Open 3 H. P. Closed 2¼ "	125	Open 21.5 Closed 18.4	....	....	....	....
Dish Washer...........	1	Robbins & Meyer Co.	....	....	Shunt	3/4	125	6	....	....	....	....
Meat Chopper..............	1	Gen. Elec. Co.	C.A.-2..	B	Shunt	3/4	125	6.16	....	....	....	....
Potato Peeler	1	Gen. Elec. Co.	C.Q.-1..	....	Shunt	1	125	....	....	....	....	....
Torpedo Air-Compressor...	2	Northern Electric Co.	....	....	Shunt	80	125	52.5	....	....	....	....
Pumps—Fresh Water	2	Gen. Elec. Co.	C. E.-2..	....	Shunt	2	125	14.5	....	....	....	....
Pumps—Sanitary	2	Holtzer-Cabot Co.	E.-5	....	Shunt	3	125	21.5	....	....	....	....
Laundry.........	1	Gen. Elec. Co.	....	....	Shunt	8	125	58.5	....	....	....	....

means of handling the valves are sometimes employed. The engines for the two types of appliances, unfortunately, require long lines of piping which must be led through compartments where the heat is inconvenient and undesirable.

The number and types of direct-current motors, together with some details, of the *Connecticut's* installation are shown in the preceding table.

Motor Action in General.

The table shows that three kinds of motors, as classified by their windings, are employed on the constant potential circuits used on board ship, the series-wound, the shunt-wound, and compound-wound; this selection of motor by type of winding results from the special aptitude of the class for a given duty, in accordance with various well-known principles applying to the motor.

The direct-current motor and the direct-current generator are convertible and have the same general methods of field winding, series, shunt, and compound; there may be a difference, however, as to output when the generator is used as a motor; for instance, a generator developing 100 k. w. at its terminals and having an efficiency of 90 per cent would receive at its shaft coupling about 111 k. w. for its engine; if now 100 k. w. are impressed at the generator terminals to actuate it as a motor to drive a load at its shaft coupling, the generator as a motor would develop only about 89 k. w. in drive, because the 11 k. w. furnished by the engine to overcome the generator losses is now taxed against the 100 k. w. input, and the output of the machine as a motor is lessened by about 11 k. w.; a motor may, therefore, be larger for the same output than a generator.

In a direct-current generator the circuits of the armature are made to cut lines of force by the mechanical power of rotation, inducing a voltage in the circuits if the field is energized. In a direct-current motor the closed loops of the armature circuits tend to place themselves in such a position that their area will embrace a maximum of the lines of force; there being a number of such loops in the armature the effort produces a continuous rotation of the armature, and the rotation enables the shaft to transmit power to a pulley at its end, or rotate a mechanical device which

is direct-coupled. The conditions of the generator are, therefore, opposite to those of the motor; the former receives mechanical power at its shaft to cause the closed loops to alter their position in the magnetic field—cut the lines of force—thereby giving out electrical power at the generator terminals; the latter receives electrical power at its terminals to cause the closed loops (carrying current) to alter their position in the magnetic field, giving out mechanical power to the armature shaft.

It is the electro-dynamic force which causes the rotation of the motor armature; the power which the motor exerts will depend upon (a) *the speed at which the armature revolves,* and (b) *the pull exerted at the circumference of the pulley,* and (b) will depend upon (c) *the radius of the pulley;* the power exerted at the circumference of the pulley is technically known as *the useful torque* (from the Latin *to twist*). The speed at which the armature revolves is governed by the consideration that its armature, revolving in a magnetic field, will also generate a voltage, since the circuits are cutting lines of force, and this voltage, called counter electromotive force (C. E. M. F.) will be opposite in direction to the entering voltage from the supply line; the effort of the motor will be to attain that speed which will cause the counter electromotive force to be equal in value to that from the supply line at the motor terminals; owing to the drop in the armature circuit—the voltage expended in maintaining the current through the armature to overcome the friction, a load in effect—the value of the C. E. M. F. can never equal the applied E. M. F., provided the field is strong. The applied E. M. F. is equal to the sum of the C. E. M. F. and the drop in the armature; but were it possible for this drop to be zero and the C. E. M. F. to be raised to the value of the applied E. M. F., no current would circulate in the armature, no useful torque would be developed, and the motor would revolve only at that speed which is necessary to maintain the C. E. M. F. The radius of the pulley is not generally considered in speaking of useful torque—or rather, it is considered for a radius of one foot—but it will be evident that if a motor has a useful torque about the axis of its armature shaft equal to the pull of a 40-pound weight over a pulley one foot in radius, that is, 40-pounds-feet, it could lift but 10 pounds if the radius were increased to 4 feet; if a pulley of large diameter is

used the force at the circumference will be small; if of small diameter, the force will be large. The case is similar for the work done in a given number of revolutions; a large pulley will have a long lift per revolution, but the weight raised will be small and *vice versa;* for a given weight, and a given torque, the size of the pulley is, therefore, limited. The useful torque of a motor represents the effort force of the motor to cause rotation against the resisting inertia of the load and, considered with reference to its pulley arm, its work done is equal in foot-pounds to

$$\frac{\text{armature current (amperes)} \times \text{field flux (Webers)} \times \text{number of armature circuits.}}{85{,}155{,}000}$$

The work done by the useful torque is also equal to the product of that torque and the speed; and the value of the work done is always equal to the product of the current and the counter electromotive force.

When a motor is under load, the load resistance slows the speed until the C. E. M. F. is sufficiently reduced to cause that difference of potential between the applied E. M. F. and the C. E. M. F., which will increase the current to a value that will produce the required torque; this requisite difference in potential is conveniently called the effective electromotive force and is the E. M. F. which produces the given current through the resistance of the armature circuit; knowing the armature resistance and the current, the effective E. M. F. for any instance will be equal to their product; the C. E. M. F. will be the remainder after subtracting the effective E. M. F. from the applied E. M. F., and the power at the instant is the product of the current and C. E. M. F.

The permissible variation of the value of the effective E. M. F. is limited by the current effects of excessive sparking at the brushes and excessive heating of the armature as in dynamos; its variation in value will be equal to from 10 per cent (for a small shunt motor at full load) to 2 per cent (for a large shunt motor at full load) of the applied E. M. F., and these motors will regulate their drop in speed within 10 per cent to 2 per cent of the normal (no load) speed, depending upon the size.

In the foregoing the conditions are based on full field, the ideal being produced by separately exciting the field; but in practice the field is excited by a voltage at the field connections derived from connections to the line supplying the motor, and

this practical method of field supply gives rise to the types of motors known as shunt-wound, series-wound, and compound-wound.

An important consideration in connection with the action of motors is that of varying the strength of the field. Assume the field strength to be reduced one-half, the armature would assume practically doubled speed to produce the C. E. M. F. and for other reductions the speed would vary in proportion; should the field strength become practically nil the flux in the armature due to the current could annul the field flux, the speed would increase indefinitely, the C. E. M. F. would cease, the useful torque would be destroyed, and the motor would tend to stop; short of this, the peripheral velocity of the armature would cause it to fly to pieces. From similar considerations, the armature speed will be decreased by increasing the field strength, because the C. E. M. F. will be produced under this condition at a decreased speed.

It is the reaction of the magnetic field of the motor armature conductors upon the field surrounding them which causes the armature to rotate about its axis.

It is the effect of the tendency to make the reaction equal to the action that causes the speed of rotation to tend to assume that value which would produce a C. E. M. F. equal to the applied E. M. F., the speed assumed being equal to that which would be required in a dynamo to produce an E. M. F. equal to the C. E. M. F. for equal field strength.

It is the mechanical friction and other losses of the motor armature which prevents the C. E. M. F. from equalling the applied E. M. F., and hence an effective E. M. F. is present under even no load conditions.

It is the effective E. M. F. which causes the current through the armature resistance at even no load conditions and which develops useful torque.

It is the increase of the effective E. M. F. which increases the current to produce increased torque for increased load, the maximum current being limited in value by heating and sparking effects. Under constant field increased effective E. M. F. is the concomitant of corresponding decrease of speed.

The Shunt-wound Motor.

In this type of motor the excitation of the field is accomplished (Fig. 135) by a winding which is shunted from the supply line at the motor terminals or their connections; hence, the field

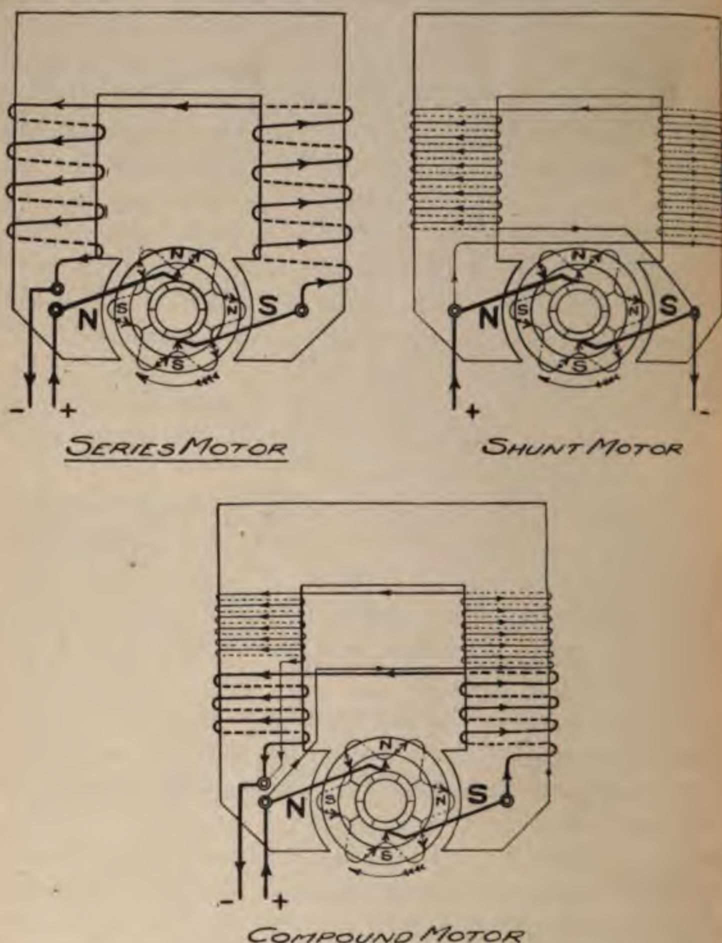


Fig. 135.—Diagram of direct-current motor windings.

is always of the same strength (the voltage of the supply remaining constant), and this condition of constant strength of field is practically that above-mentioned for the full field of separate excitation.

This type of motor will develop but comparatively small differences of speed, owing to the strong field, in generating the variations of C. E. M. F. necessary between no load and full load, and the speed will vary between these limits of load only about 2 per cent for a large motor and 10 per cent for a small motor. This good automatic regulation of the speed makes such speed practically constant and gives rise to the statement that *a shunt motor gives constant speed under variable load* (within its operating limits of load) and that *a shunt motor is self-governing.* The effect of increasing the load is to slow the motor a few per cent until the effective E. M. F. produces the necessary current; sudden variations of increase of load, and overload, produce a rush of current in the armature, which devices in the supply line can be made to control to below the permissible maximum.

Since the field is at full strength there can be no important accession to the field strength on starting, hence the useful torque will not be increased at starting over the full-load conditions as compared with a series motor.

The Series Motor.

In this type of motor the excitation of the field is accomplished (Fig. 135) by a winding which is in series with the armature winding and the excitation of the field is wholly due to the current circulating in the armature at the instant. Under no-load conditions this current will be small and the field be very weak; hence the armature must assume high speed to produce the C. E. M. F. This is the practical case explained for a motor operating under weak field, and so likely is a series motor under light-load conditions to assume that peripheral speed which could destroy the armature that it is mandatory that *a series motor shall always be sufficiently loaded to control the speed within safe limits;* a caution in this direction is that a series motor could destroy itself by excessive speed if all load was suddenly removed from it. The series motor having a variable strength of field, increasing and diminishing in proportion to the current, has necessarily a wide variation in speed between its full load and (practical) no-load conditions, and does not approach self-governing requirements.

At starting and when the current is small in proportion to the diacritical current (that current which will bring the magnet cores up to semi-saturation), the torque is proportional to the

square of the current, and the useful torque is large in comparison with that at full load; this heavy torque at starting is the chief advantage of the series motor.

The wide variations in speed of a series motor usually result in producing an excess of torque for the given load, and this develops an acceleration of speed; this property, together with the great starting torque, is the basis of the commercial use of a series motor for hoists, elevators, and railways; the load starts more promptly, and once started the speed of travel is accelerated.

The Compound Motor (Fig. 135).—This type of winding is a combination of a series and shunt field winding on the same field core and may be *cumulative* (sometimes styled *additive*) when the effect of the series winding is to assist the shunt winding as in a dynamo; or *differential,* when the effect of the series winding is to oppose that of the shunt winding.

The *cumulative* method has the advantage over the simple shunt winding of supplying to the motor that excess starting torque which is lacking in a shunt-wound motor, but the governing, once started, will be inferior to that of a shunt motor but better than for a series motor, and will depend upon the relative strength of the series and shunt field.

A second advantage is that on sudden removal of the load the shunt field will still produce strong field and the motor will not race away. A third advantage is that the series field, by accession of current in its winding, will assist the shunt field in producing torque to overcome increased load, though usually at reduced speed.

The *differential* method produces closer self-governing of the motor than the plain shunt winding; for, as the load is increased, the current circulating through the series winding is increased, weakening the total motor field, and the armature tends to speed up under the weakened field conditions. By proportioning the series and shunt windings, it is, therefore, possible to correct the tendency of a shunt motor to slow down when under load or to increase in speed when unloaded, even within its small natural operating limits, and thus more closely govern the speed. The method is not employed for compound motors on board ship; its close self-governing properties are sometimes availed of for commercial uses where such properties are the major issue.

The availability of the properties of the various types of windings for shipboard use, on constant potential mains, are contrasted as follows:

The series motor is valuable for its great starting torque and speed of action, properties that are well suited to the operation of winches and rammers and for work of this kind the series motor is in general use. An objection to this type of motor for winch practice is the fact that the speed rises dangerously high if the load is thrown off (the fall parting, for example), the strength of the field being diminished by the rise of the C. E. M. F., and consequent drop of current. The motor makes the attempt to attain the speed at which the C. E. M. F. equals the applied E. M. F., each increase of speed diminishing the field current and in turn the C. E. M. F., and calling for higher speed to attain to the applied E. M. F.; theoretically, the speed of the series motor under such circumstances is infinite, but the practical limit is found in the fact that friction and internal losses always make something of a load, so that no motor ever runs absolutely light; in the end, the limiting qualification is the ability of the armature to remain intact under the high peripheral velocity, and the chances are assumed in commercial crane practice from a comparison in cost, the series type of motor being comparatively cheap.

The shunt motor preserves a practically constant speed; it has, however, the great defect of having small starting torque as compared with a series motor under similar conditions. The special adaptation of the shunt motor is to start with no load or with a light load and afterwards preserve a practically constant speed; the apparent exception of the load imposed by turret turning, gun elevating, and whip hoists, has, therefore, to be met by large power in comparison with the actual required for the duty. The great advantage of the shunt motor is, then, its good self-governing features, the property of constant speed, and this property is preferable for the vast majority of motors installed in the list on pages 254 to 257. It will be noted that of motors of one horsepower and above the most are shunt motors, and for a majority of the *classes of duty* the shunt motor is also preferred and best.

The compound motor, with cumulative winding, is very generally installed for the operation of electrically operated water-tight

doors and power hatches; it is installed for the operation of winches on board of the *Connecticut*.

Its advantage for use with water-tight doors is due to the good starting torque and that when the door meets an obstruction in its path—such as the wedges in case of the usual door, or wedges and coal over the threshold, in case of a bunker door—the new resistance slows the armature; the effective E. M. F., and consequently current, is increased; the series field is increased, strengthening the total field; more current results and the action becomes cumulative. And, although the armature is slowed, the large increase of field and current increases the torque; the net result is that the motor exerts a strongly increased power in closing the door, but at reduced speed, the latter not being an important disadvantage for the particular duty.

For the case of the power hatch the compound motor has advantages of good starting torque combined with fairly steady speed after starting.

Its advantages for winches resides largely in the protection afforded the motor against racing in case of loss of load, an important feature in ship duty.

Motor Reversal and Control.

Motor Reversal.—If two generators, one series-wound and the other shunt-wound, have been connected up as generators and both are to revolve clock-wise, for example, and current is supplied separately to each at constant potential to drive them as motors, the current entering at the positive, generator, terminal in each case, it will be found that the *shunt-wound machine* continues to revolve clock-wise as a motor, and the *series-wound* machine revolves counter clock-wise; the former has assumed the same direction of rotation as when driven as a generator while the series-wound machine rotates in the opposite direction to that in which it was driven as a generator. This arises from the fact that in the *shunt-wound* machine the current in the field is in the same direction as when operating as a generator and the directions of the lines of force are the same; and hence, to oppose the applied voltage, the armature must revolve in the same sense as when operating in the generator; the case is different for the *series-wound* machine because the applied voltage reverses the

field, and hence the motor must build up a C. E. M. F. by a counter-clock-wise rotation.

If now we reverse the direction of the applied E. M. F. by connecting its positive side to the negative generator terminal, the shunt-wound motor will still rotate clock-wise, and the series-wound, counter clock-wise; reversing the polarity of the applied E. M. F. has, therefore, effected no change in direction of rotation in either case and for the reason that the reversing process used is applied as well to both field and armature; reversal of direction of rotation of the motor is, therefore, to be accomplished by reversing either the field current, or the armature current (the ordinary method), *but not both.* In a shunt motor the object is readily accomplished by constant excitation of the field and reversing the motor by reversing the current entering the armature; in most shunt motors installed on board ship for which reversal is desirable the fields are already separately excited for speed control; a reversing switch in the armature leads makes reversal a simple problem.

The design for a reversing switch for a series motor breaks both the armature and field current at the same instant, that is, both field and armature have no applied E. M. F. at the "off" position of the controller, and hence the proper conditions obtain for connection to the line; this is different from the condition for a shunt motor whose field is kept excited directly from the mains whatever the position of the reversing switch, whether "off" or "on" in either direction.

Motor Control.—This term is applied to the operation of circuit devices by which the motor can be operated at varying speeds; it commonly embraces also that type of apparatus for starting motors which are intended to operate at rated speed and which are known as starting rheostats or starting boxes, which, though not intended in any sense to vary the speed, are still a part of any speed control design, as regards their simple features at least. The systems of control used in the Navy are starting rheostats, the Leonard system, the Day system, and the Panel (or Multi-voltage) system.

Starting Rheostats.—It is evident that a motor must have time to start and develop C. E. M. F. before the total E. M. F. of the supply line can be applied; otherwise, an enormous current

would result which would seriously injure the brushes and commutator and could destroy the insulating materials in the armature, or, in common parlance, would probably burn out the motor; and the object of the starting rheostat is to provide a means of supplying the total applied voltage gradually, though in a fairly brief time, and thus afford the requisite time to overcome the inertia of the armature and establish the magnetic reactions; the simplest method is to insert a variable resistance in the supply line.

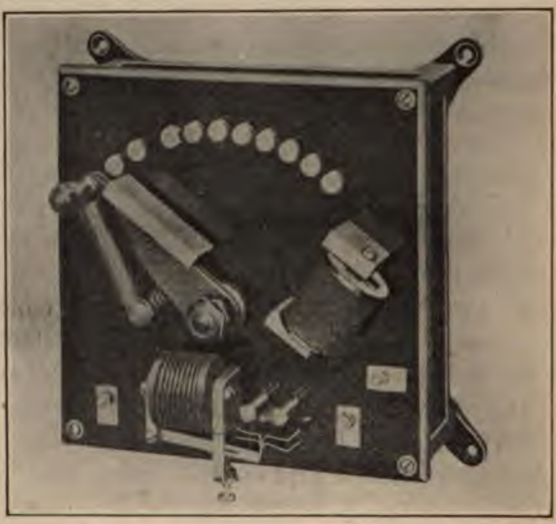


FIG. 136.—Motor-starting rheostat with no-voltage and overload release.

A type of starting rheostat for a shunt motor which is complete in all essentials is shown in Fig. 136. The design consists of a non-combustible box in which the resistances are enclosed. The cover, to which the various electrical connections are secured, is made of some non-conducting material, more often slate or marble. Near the top of the cover are brass studs or blocks which pass through the cover and are connected the one to the other through the resistances; these resistances are not necessarily distributed equally between the blocks but may differ or have a series-parallel connection according to convenience of design, and the resistances may be of any form, coil, metal sunk in enamel, ribbon in asbestos, etc., as may be best for compactness.

The diagrammatic connections are shown in Fig. 137, from which it will be seen that the spring lever can be gradually passed, a few seconds per block from the left-hand blocks on to the right, passing from block to block and cutting out resistance until it finally reaches the extreme right-hand block, when all resistance due to the rheostat is cut out and the motor armature is receiving the full voltage of the supply line, the losses of voltage before arriving at the last block having been dissipated in heat in the

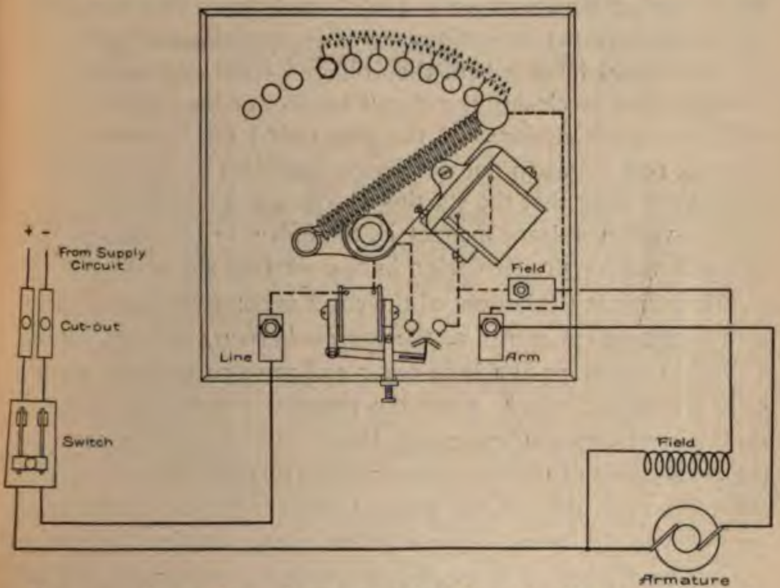


FIG. 137.—Connections of motor-starting rheostat with no-voltage and overload release.

rheostat. The three left-hand blocks shown are merely mechanical adjuncts as a rest for the spring lever, and at which the circuit is open, or "off."

It will be noted that *the motor field is energized before any voltage is applied to the armature,* as will appear from the connections; this is mandatory in starting shunt motors, which would on account of weak field start under irregular conditions of excess of current, sparking and heating, were the field connections shunted directly from the armature terminals as in a short-shunt dynamo; it is essential that a comparative period of time elapse in getting the field to full strength.

The device shown on the right side of the cover is an electro-magnet connected in the field circuit and is called *the no-voltage-release magnet;* it holds the spring lever to the right-hand block by the attraction of its pole pieces on a soft-iron armature attached to the spring lever as long as any current is passing from the supply line; if the voltage fails from the opening of a circuit breaker or blowing of a fuse the spring throws the lever back to the left-hand blocks since the no-voltage-release magnet can no longer attract the armature and hold the lever. This safeguards the motor against the contingency of leaving the spring lever on the right-hand block when, the voltage of the line having been re-established by closing the circuit breaker or by a new fuse, the total electromotive force of the line would reach the armature when at rest, or when not developing sufficient C. E. M. F.; this is the very thing that the starting rheostat is intended to prevent. The no-voltage-release magnet is, therefore, to be regarded as a *sine qua non* for proper design in any starting rheostat.

The device at the bottom of the cover is connected in the armature circuit and is known as the *overload-release magnet.* It has a pivoted armature at whose outer end are two contacts, electrically connected, which, when the magnet armature is attracted, short-circuit two binding posts, shown; these binding posts are the connections of the no-voltage-release magnet, and these, being short-circuited, deprive the magnet of current; hence, the magnet releases the spring lever and the spring brings the lever to the left-hand block as in the ordinary case of the operation of this magnet for no-voltage release. The device protects the armature from any current whose value is greater than that permissible, and its magnet is so adjusted as not to operate below that current. An intent of the overload-release magnet is, however, to guard against the overload on a motor which is so often occasioned by the carelessness of that attendant who, in starting the motor, moves the lever too rapidly over the blocks; the inability of the motor to establish its speed and the necessary C. E. M. F. would result in such a case in a large excess current; this particular intent in this device is said to have given rise to a characterization for this and other designs on similar lines, particularly in alternate-current work, as a "fool-proof" device. Notwithstanding the protection afforded by the overload-release de-

vice, it is frequently omitted in designs of starting rheostats and a fuse in each pole substituted.

It is important to remember that the starting rheostat is not to be used as a controller to vary the motor speed. Although the variable resistance can effect a control of speed the resistances are designed to endure the current only for that short time which is necessary to start the motor, hence any attempt to regulate the motor speed by leaving the lever on other than the armature stop would result in unduly heating the resistances and they would finally burn out; and only because they were not designed for a protracted heating effect of the current used in starting.

The Leonard System of Control.

This system was designed by Mr. H. Ward Leonard, to reduce to the lowest practicable limits the amount of energy required in starting and operating motors. To start a motor properly it is necessary to apply at first only a small proportion of the maximum voltage of the circuit from which it is actuated, and gradually increase to the full voltage of the line. In the customary methods, this is accomplished by a rheostat whose resistance, combined with that of the motor armature, is sufficient to keep the current to about 1 or 1½ times the rated full-load current at the time of first closing the circuit; the result is that half or more of the fall of potential takes place in the rheostat and becomes lost energy; but *if the voltage is generated only in the amount actually required for the time being,* this rheostat loss can be obviated, to the economy of energy.

The system is employed for the shunt motors for turret turning, and in recent practice for gun elevating, and combined with it is the advantageous expedient for refined control of speed, separate excitation of the motor fields independently of the armature circuit, and a further combination for reversal is afforded by the separate excitation in that the excitation being constant in direction, reversal is easily accomplished by merely reversing the entering direction of the armature current. All these processes—varying the generator field to control the voltage, separate excitation of the motor fields, and the reversing switch—are included in the design of the controller device and operated in a simple motion of the controller lever.

As applied to turret turning and gun elevating, Mr. Leonard's method is shown in an elementary way in Fig. 138. L and L^1 are the line wires of the supply circuit from the switchboard. GF and MF are the generator and motor field circuits that are excited by the supply circuit. The voltage of the generator field can be controlled in amount as required by the variable rheostat, R. The motor field, MF, is separately excited from any lines leading from the switchboard other than those connected up with the generator, GA (or that employed for operating the turret-turning motors); the motor fields are, therefore, constantly excited to the full voltage of the line feeding them. GA and MA are the armatures of the generator and motor, respectively; RS is a reversing switch through which the direction of the current flowing into the terminals of MA can be changed.

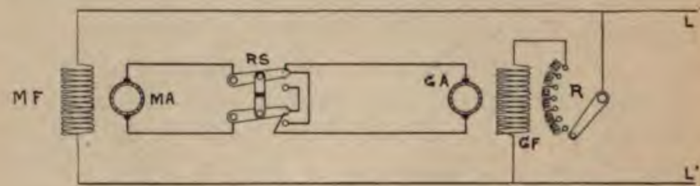


FIG. 138.—Diagram of Leonard system of control.

The operation is as follows: The generator is driven at the constant speed required for its *full output* by some prime mover such as a direct-connected engine (or motor, in motor generators). When the rheostat in circuit with the generator field is open, no voltage is generated in the generator armature; on closing the rheostat circuit, the current flowing will magnetize the generator field and the generator armature will generate a voltage, and, when the reversing switch is closed, this voltage will be that at the brushes of the motor armature also. As soon as the voltage has risen to a sufficient value, the current, which has been increasing as gradually as the voltage, will finally produce just the requisite torque to turn the motor armature. As the motor field is constant and at full strength, the necessary torque will be produced with a minimum of current.

It will be seen that there are no losses in motor armature rheostats, and that no sudden shock has been applied to either the generator or motor. The speed of the motor may be increased

gradually to the maximum, which will obtain when all the resistance due to R is cut out of the generator field as the generator will then give its maximum voltage.

The direction of rotation of the motor is changed by the use of the reversing switch which reverses the polarity of the motor armature terminals, the current entering oppositely. A strong braking action can be obtained by short-circuiting the motor armature at the time when the load tends to rotate that armature after the generator voltage has been cut off, as the motor will then be acting as a generator, through a low resistance, and the drag on its armature will tend to stop it.

The method of practical application of the system is explained in connection with the connections for turret-turning motors.

The Day System of Control.

The system was invented by Mr. Maxwell W. Day of the General Electric Company.

The controller is similar to the well-known street car style of construction, but has a system of connections especially adapted for hoisting work (for which the control of the speed in lowering is a very important matter on account of the high efficiency of the hoisting mechanism) the system permitting the load to overhaul for hoists in which the ordinary crane practice of using a series motor and solenoid brake would be unsatisfactory. The connections are so arranged that in hoisting the load a portion of the rheostat is introduced into the armature circuit, but not quite sufficient to start the full load on the first hoisting notch, or position, of the controller. The second notch cuts out sufficient resistance to cause the load to start, and the other points on the controller will give a control of speed. This system of connections is shown in the elementary diagram (Fig. 139), which represents the successive steps, 5, 4, 3, 2, 1, of cutting out resistance, until full speed is reached. As the resistance is turned out of the circuit, the speed increases, and as the resistance is turned into the circuit, the speed diminishes, until on the "off" position, the main circuit is broken, and the armature is short-circuited on itself, producing a powerful brake effect, causing the armature to instantly stop and prevent any rapid descent of the load, although the load will descend slowly unless some other mechani-

cal device is provided to prevent it. A contact is provided on the controller to energize the solenoid brake magnet, so that the solenoid armature is lifted up and the brake released whenever the controller is turned away from the "off" position; as soon as the controller is turned off the magnet loses its strength and the brake is immediately set.

As the load would not always be sufficient to start the motor easily from a state of rest, it is necessary to provide some means of causing the motor to operate as a motor in case the load will not start it as a generator. For this purpose the connections are made as shown in the diagram, "lowering" (Fig. 139), the rheostat being connected across the line; and on that account the rheostat is made of considerable more resistance than is required for starting the motor in hoisting in order to prevent

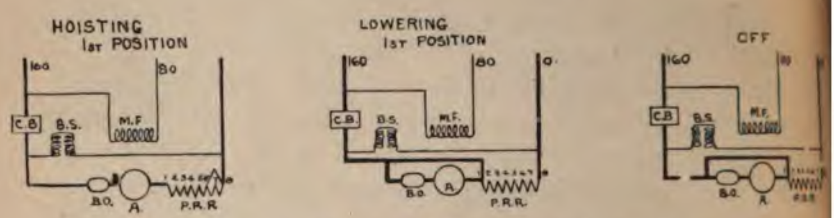


FIG. 139.—Diagram of Day system of control.

useless waste of current through the rheostat; the resistance is such that this current may amount to 15 or 20 per cent of the full-load current of the motor. In the first lowering position of the controller for this arrangement, the armature is short-circuited on itself and both lines are connected to the rheostat. The next position puts the armature in multiple with a portion of the rheostat; the armature will now receive current from the line, in case it does not start of itself or it will produce a current through this portion of the rheostat in addition to the current passing through it to the line. In the next position, more resistance is put in multiple with the armature, and the greater current is taken from the line, if the motor does not start, or a higher speed as a generator is produced if the motor acts as a generator. In this system this portion of the rheostat may be considered as being in multiple with the armature as regards the

current received from the line, and in series with the armature as regards the current produced by the armature itself.

The feature of the Day control is the electrical braking action of the motor armature when, as actuated by the load, it is operating as a dynamo.

The electrically operated mechanical brake, or solenoid brake, often used as an adjunct to this system of control is shown in diagrams *A* and *D* of Fig. 140.

1 and 2 are the two solenoid coils attached to, and embracing the cores of, the yoke 14. A weight, 3, with cores, 4, 5, is attached to the brake lever, 6. As long as the coils 1 and 2 are

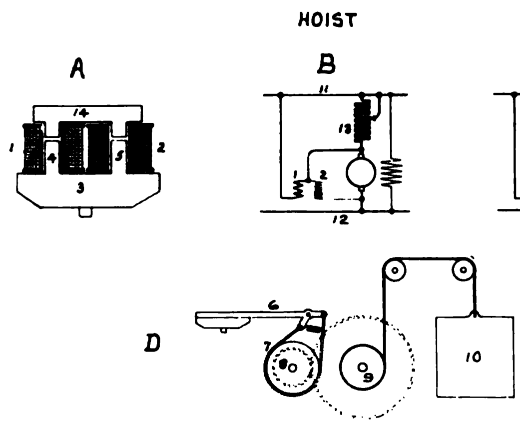


FIG. 140.—Day system differentially-wound.

not energized the weight, 3 (and brake lever, 6) will be free to fall, and from the arrangement of the pivot of the brake lever as shown, and the brake band, 7, the weight of the brake lever will ***set up the brake band*** against the brake wheel, 8, attached to the motor armature shaft; if the coils 1 and 2 *are energized* the cores 4 and 5 will be attracted and the brake lever will *release* the brake band from the brake wheel. 9 represents the drum or gypsy around which is taken the fall or rope for hoisting or lowering the weight, 10.

The application just described contemplates that the brake solenoid coils shall be similarly wound and both coils shall be connected in series across the mains. In the more recent patent, solenoids 1 and 2 (Fig. 140) are not wound alike but have a

difference in their number of turns and size of wire as shown. The connections are made, as shown in diagrams *B* and *C*, to a contact at the solenoids to which one end of each coil, 1 and 2, is led; 1 is then connected back to the positive main, 11, while 2 is connected to the motor armature circuit. In hoisting, diagram *B*, solenoid 1 shunts the resistance, 13, while solenoid 2 shunts the armature. Before the motor starts in lifting, substantially the whole electromotive force of the line will be consumed by the resistance, 13; coil 1 will be strongly energized, while coil 2 will receive practically no magnetization, being short-circuited by the armature; but, as the motor begins to attain speed, its increase of counter electromotive force will shunt an increasing amount of current through coil 2. When the motor has reached full speed, nearly the whole electromotive force of the mains is consumed in the motor armature; coil 1 now ceases to perform its function of holding the brake released, but coil 2, receiving the full potential of the mains, is sufficient to prevent the lever arm from dropping and setting the mechanical brake. This office coil 2 is able to perform the more easily since the cores, 4, 5, have already been drawn close to the yoke, 14, and the magnetic reluctance between the cores and the yoke, 14, is, therefore, small. The device requires only that loss of energy which is due to coil 2 and which is substantially less than for two similar coils connected in series.

In lowering, diagram *C*, the connections of the brake solenoid are altered. Current can still flow through coil 1 as before, but it passes by the connection, shown below the resistance, out of the negative main. Since the armature current is reversed the direction of the current through the circuit of coil 2 is also reversed, as it shunts the armature, and would tend to demagnetize the coils, 4, 5, by neutralizing the action of coil 1, and, at the full-speed position, would practically accomplish it and cause the brake to be applied were coils 1 and 2 of the same resistance; but as the construction of coil 2 is of finer wire its magnetizing power is small and the cores retain enough magnetism to hold the brake released. When the motor acts as a dynamo, coil 2 holds the friction brake released, but sets it when the motor slows down and the current which the motor is generating lessens.

The practical method of application of the system is explained

in connection with the connections for the 13-inch turret ammunition hoist.

The Panel (or Multi-voltage) System of Control.

This system is a method of changing from a higher to a lower voltage and *vice versa* for some motors on the *Kearsarge* and

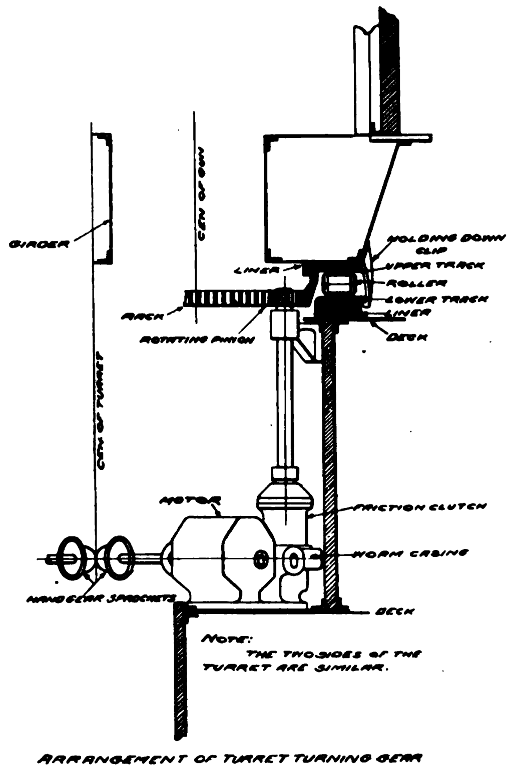


FIG. 141.—Turret-turning system. Elevation.

Kentucky which can be energized by multiple voltage; it is explained in connection with the particular motors and class of duty.

Turret-Turning Motors.

One of the latest arrangements for the turret-turning system is shown in the sketches of Fig. 141 (elevation), and Fig. 142 (plan).

Two motors, independent of each other, have their shafts con-

nected together by beveled gears. Each motor has a bevel pinion on its shaft which meshes with a similar bevel pinion on a worm shaft; the worm drives a horizontal worm wheel which is connected to a vertical shaft through a friction clutch; and the vertical shaft, through a pinion at its upper end which meshes with the rack at the base of the turret, drives the turret. The friction clutch is set tight enough to drive the turret under usual operating conditions, and is of the cone type. Should the clutch be overloaded it will slip and protect the gears.

The beveled gear wheels are fitted with sprockets for attaching hand gear by chain in case the motors are disabled.

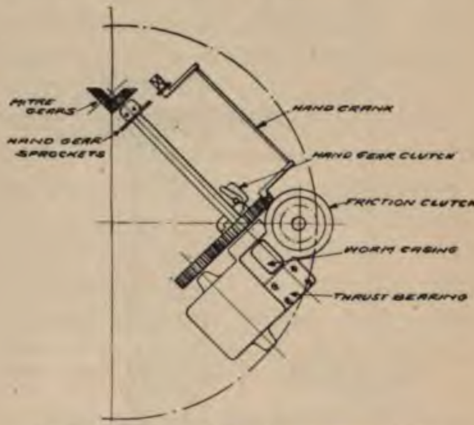


FIG. 142.—Turret-turning system. Plan.

[NOTE 23.—In an older system installed the motors are secured to brackets on the walls of the handling room and at the proper height for engaging the gears. Both motors revolve in the same direction, both driving through bevel gears to one shaft which runs across the turret; the object of the cross-shaft is that one motor may drive the turret by driving both pinions should the second motor be electrically or mechanically disabled, and also to permit one motor to revolve the armature of the other motor through the bevel gears, instead of through the worm wheel and worm, should the other motor fail electrically. This shaft carries at one end a right hand and at the other a left hand worm, each of which engages a worm wheel at the top of a vertical shaft. At the lower end of each vertical shaft is a pinion which meshes with the circular rack inside of the barbette and thus drives the turret. The worm wheels are connected to the vertical shafts by cone friction clutches which can be adjusted by nuts to carry the desired load, or to slip off, if the load be exceeded, to prevent damage to the driving mechanism from an excessive overload.

such as occurs when firing one gun or from the impact of a projectile on the outside of the turret tending to produce a rotation of the turret independently of the motors.]

The Motor.

A type of motor used for turning 8-inch turrets superimposed on 13-inch turrets, unbalanced, is shown in Fig. 14~~6~~3. It is rated at 50 horsepower, and is of the enclosed, armored type, 4-pole, and classified by the General Electric Company as C. B.-11-B.-1. It is shunt-wound and is designed for an armature speed of 400 r. p. m., and an input of 540 amperes at 80 volts, full load.

The magnet frame is an octagonal steel casting made in two pieces. Feet are cast on the lower frames and are drilled for bolting the motor to its foundation. The upper frame is held in position by six steel tap bolts.

The pole pieces are of cast steel and are bolted to seats bored in the magnet frame and located at 45 degrees from the horizontal. In assembling they must exactly fit their seats or the air gap will be altered and the pole tips be likely to strike the armature, as there is no dowel pin or key.

The armature bearings are cast on the lower frame and are fitted with removable caps and split linings. They have large pockets for catching the waste grease. The caps are held in position by steel bolts and have large grease boxes cast on which are fitted with composition covers, held in place by copper-plated steel springs. The armature-bearing linings are cast iron, babbitted, and made in two halves; they are provided with slots for admitting the grease lubricant to the shaft.

The armature is the usual slotted-core, barreled-wound type.

The brush rigging consists of a revolving cast-iron yoke, made in two pieces, fitting on the commutator end bearing. The yoke supports four insulated brass studs which are cross-connected by 288,000 cm. cable, rubber-insulated, and braided to 1.1 inches outside diameter. Each stud has six brush holders with carbon brushes, 1 by 1¼ by 2½ inches, similar to those used on the form G dynamo. The brush-holder springs are adjustable to give proper tension to the brushes. The brush-holder cables are brought out through the front end of the lower frame by two brass connection bolts which are insulated from the frame by fiber washers and bushings.

There are three large rectangular **hand holes** in the upper frame immediately over the commutator through which the brushes can be sand-papered and fitted; they are provided with cast-iron covers, made water-tight by soft rubber gaskets, and held in position by bronze wedge bolts. The ends of the upper frame have semi-circular openings fitted with malleable-iron covers which are held in place by bronze cap screws and made water-tight by soft rubber gaskets. If desired, the semi-circular covers can be left off for ventilation. To allow for examination and adjustment of the lower brushes, two circular hand holes

FIG. 143.—Motor for turret turning.

are cast in the commutator end of the lower frame and are fitted with cast-iron covers held in place by springs. To sand-paper the brushes on the lower studs, it is necessary to disconnect the brush-holder cables and revolve the brush-holder yoke until the lower brushes are brought to the top where they can be reached through the rectangular hand holes.

The (two) motors for turning the single 12-inch balanced turrets are of similar construction. They are rated at 35 horse-power, at 80 or 125 volts, and also have a rated speed of 400 r. p. m.

The (two) motors for turning each of the single 8-inch balanced turrets follow the same general design, having an output of 15 horsepower at 125 volts, and a rated speed of 400 r. p. m.

The Controller for the Turret-Turning System and its Operation.

This especial type of controller, known as the "P" type, is used when the voltage of the *generator field and armature* is to

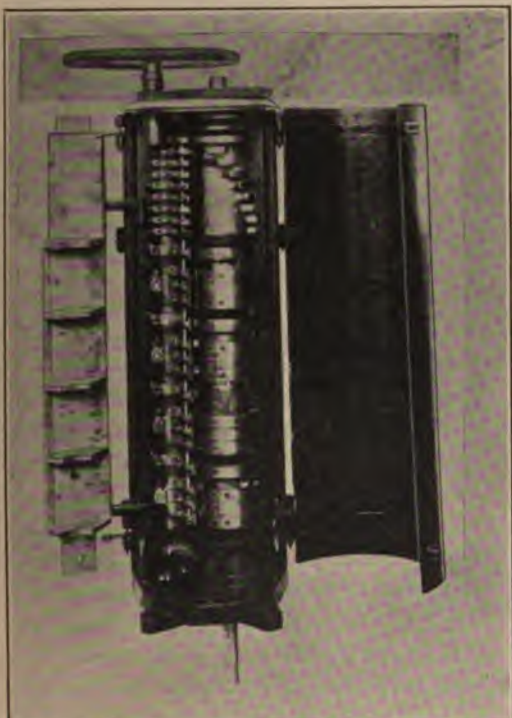


FIG. 144.—Controller for turret turning. P-2 type.

be varied to change the speed of the motor, on the Ward-Leonard system, and is, therefore, called a variable voltage controller. It is radically different from other controllers, both in design and system of control; while it retains the general features of all controllers, the proportion and arrangement of its contacts are quite different.

There are two typical varieties: that used with the superimposed turret system, and known as the P-2 controller; and that used with the single 12-inch balanced turret and known as the P-10; both notations are those of the General Electric Company.

The P-2 Type of Controller.

This typical design is shown in Fig. 144 and is that used in the *Kearsarge* for the turret-turning system.

The frame is a cast-iron plate, having a projecting shelf or ledge at the bottom, provided with four drilled lugs for fastening. The cover is of sheet iron, semi-cylindrical in shape, and held by hinges and swinging bolts. At the bottom is a bearing for the cylinder shaft, the upper bearing being in the cap-plate. To remove the cylinder, take off the cap-plate and pull it straight up, as the shaft extends through the bottom of the controller and the lower bearing has no cap.

The cylinder is supported on a steel shaft 1½ inches in diameter, and consists of a wooden cylinder, pinned to the shaft, supporting cylindrical castings for the contacts. There is one cylindrical casting at the top, with one continuous ring and eight pairs of short segments for controlling the field of the generator. There is so little danger of burning these segments that they are not provided with removable pieces. Below these there are two castings on one side of the cylinder and three on the other, which take the armature connections and are provided with removable segments or contact rings. Of these, four on each side for making the armature connections are 3 inches wide; there are three others for auxiliary rheostat connections with are 1 inch wide. All of these segments are provided with removable tips that may be removed without removing the entire segment.

At the bottom a coupling connects the controller to a vertical shaft which is mechanically operated by stops at nearly the limit of travel of the turret, turning the cylinder to the "off" position. This safety device prevents that degree of rotation which would allow the guns to strike the superstructure. Dependence should not be placed upon it except for emergencies, but it will usually serve to notify the operator when he is approaching the limit of train by automatically moving the handle.

On the wooden blocks supported by the frame are several

contact fingers, insulated by the block from each other and from the frame. The fingers are stamped from copper and are held in position by springs and adjusting screws, so that when the cylinder is rotated its segments will make firm contact with the fingers whose springs give sufficient pressure to ensure good electrical connection. The fingers are supplied with binding posts in which wires or cables are fastened, making the necessary connections between the line switch, motor, and rheostats. The wires are carried directly out through the back of the frame, being insulated from it by rubber bushings. The fingers are fastened in their bases by small screws which permit the replacing of any which may be injured. The adjusting screw is provided with a check nut that the screw may not jar loose after the finger has once been adjusted.

The bases are fastened to the wooden block, and the wooden block to the controller frame, by screws.

There are two kinds of contact fingers used; those at the top are ½-inch wide and have bases which are provided with binding posts for the connections to the generator field and rheostat; the other fingers are 1-inch wide and are arranged in sets of three each on a common finger base for the main contacts, and single fingers for the auxiliary contacts. The finger bases are provided with binding posts for the main leads. On the back of the controller are two sets of three fingers each, mounted and connected to a brake rheostat.

Blow-out Magnet.—In order to reduce that burning of the segments and fingers which is likely to result from the operation of the controller, a magnetic field is provided which has the effect of instantly breaking the electric arc formed when a circuit is broken. This magnetic field is produced by a spool or coil surrounding the lower end of the cylinder shaft. In addition a steel pole piece is supported over the fingers which is connected magnetically at the bottom to the bearing of the shaft, forming a magnetic circuit consisting of the shaft, bottom of the controller frame, and the pole piece, the circuit being completed by the air space between the pole piece and the shaft, and supplying a magnetic field along the end of the fingers. There is some magnetic field on the other side of the controller cylinder, between it and the back of the controller, but only that portion formed between

the pole piece and the shaft is employed in blowing out the arc. The magnet coil is located at the bottom of the frame and surrounds the lower end of the cylinder shaft and its bearing. The magnet spool is provided with two binding posts, one of which is connected to one of the finger bases, and the other to the circuit.

Arc Deflector.—To more thoroughly insulate the fingers from each other and from the cylinder and pole piece, strips of fireproof insulating material are provided, extending between the fingers and pole piece, with division plates extending between the fingers themselves. The division plates are placed between the main contacts only, as the current for the field contacts is so small that more are not necessary.

Star Wheel.—That the operator may judge the position of the cylinder while operating, without looking at it, a wheel is fastened to the cylinder shaft (in the usual controller this contains several notches or teeth); these engage a roller, supported on the end of the pawl, which is pressed against the star-wheel by a spring. As the cylinder is rotated the pawl offers resistance to the movement of the handle, and, as it moves into the notches, the effect is plainly felt by the operator. The controller handle should rest only in the position shown by this pawl and star-wheel, as it is at these points that the fingers make the best contacts with the cylinder; it should not be left at intermediate points. In the particular type used for turret motors the star-wheel is located at the upper end of the shaft and contains *but one notch*, located at the "off" position; others are not necessary as the main circuit is broken at the time of starting and stopping and the current controlled by the upper part of the cylinder is small. The star-wheel gives the additional advantage of making a quick break at the time of passing from one position to another, the tension of the spring helping to turn the cylinder after the roller has passed the point between two notches. It is essential that this controller should operate easily and not interfere with the training of the gun; it should have a plainly marked point at the "off" position.

The cap-plate is a semi-circular brass casting at the top of the controller containing the bearing for the cylinder and a bearing for the secondary shaft which is connected by gearing to the

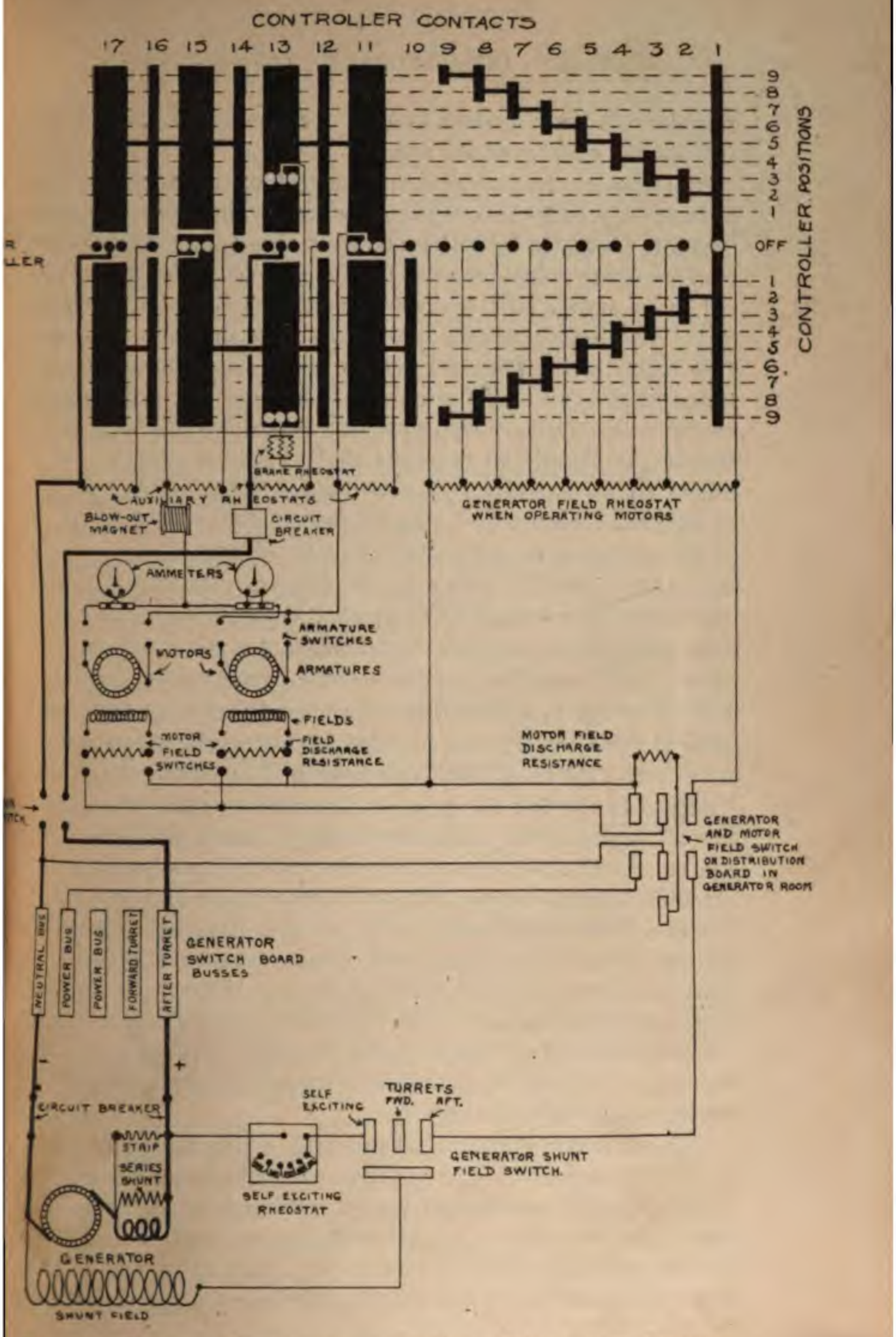


FIG. 145.—Diagram of turret motor connections of the *U. S. S. Kearsarge.*

cylinder. It has a pointer to show the position of the gear and indicate the position of the cylinder.

The handle, instead of being carried on the main cylinder shaft, as in other controllers, is carried on the secondary shaft, which is connected by pinion and gear of about 4 to 1 reduction to more easily operate the main cylinder. While the main cylinder turns nearly half a revolution in each direction from the "off" position, the handle itself turns more than three and one-half revolutions. The gear carries marks on its top surface to show the position of the cylinder. If it is desired to operate the cylinder directly the pinion gear may be easily removed and the handle put directly on the main shaft, in which case the index points on the cap-plate will show the position of the cylinder. If desired, a hand-wheel may be used instead of the handle.

The operation of the controller as an adjunct to the Leonard system of control is shown in the diagram of Fig. 145, which represents the connections as applied to the after turret of the *Kearsarge*. The diagram contemplates the operation of two motors in the same turret from a single dynamo room generator, and in tracing it, it should be remembered that most power circuits of the *Kearsarge* are installed for both three-wire and two-wire use, explaining that switch-board bus which is marked "neutral bus"; that the 50 k. w. generator operating the motors has a German silver connecting strip, by which the series field can be partially cut out and the generator run mainly as a shunt machine, a small amount of excitation by the series field being retained in the shunt action of the strip to have its slight effect on the voltage of the generator, thereby causing the turret to start more promptly than would be the case if the shunt winding alone were employed; and also that any one of the seven, 80-volt compound-wound dynamos in the ship can be used either for lighting, or for running either the forward or after turret, or for other power or electrical uses.

The generator armature, shunt field, series field, and series shunt are shown in Fig. 145. The circuit breakers connect the terminals to the neutral and after-turret bus bars on the switch-board; the strip shown just above the series shunt, is located on the same base with the circuit breaker next to it, and is that strip which partly, but not wholly, short-circuits the series field

when the generator is to be used for operating the two turret motors shown.

The "self-exciting" rheostat is the one used with the dynamo when running for all purposes other than turret turning; in such cases the switch is closed across from the connection marked "self-exciting" (the strip at the circuit breaker must then be open).

The controller cylinder performs two distinct offices. The upper part has nine contacts which are connected by fingers and leads to the generator field rheostat. The lower part supports a number of semi-circular segments, of which those marked 11 and 15 connect with the motor armature, and 13 and 17 connect with the switch-board; these segments form the reversing switch between the generator and the motors. Attached by a pair of auxiliary contacts to the two divisions of segment 13 is a brake rheostat, whose circuit to the motor armatures is completed on the "off" position through segments 11 and 15; the rheostat introduces a brake resistance across the motor brush terminals when the controller is off, which checks the momentum of the turret and the motor armatures due to the energy required to drive the motor armatures as dynamos, thus generating current through the brake rheostat. This current decreases with the speed, becoming zero when the turret is at rest; it gives the greatest braking effect at first, diminishes as the turret is retarded and produces a smooth stop.

The initial current in the brake circuit is dependent upon the speed of the turret when the circuit is closed, and it is desirable that the turret speed should be as low as possible in order to reduce the current and prolong the life of the fingers and contacts in the controller. If the turret is turning at full speed and the controller handle be moved very rapidly to the "off" position, a current of 1000 amperes or more may be generated through the brake resistance and cause roughness of the finger contacts.

As the motors will generate current through the dynamo armature circuit, when the controller handle is turned to the position for lower speed than that which the turret is actually running, a braking effect is produced which will not require that any circuits be closed or opened and, therefore, produce no arcs. This is the desirable method of retarding the speed of the turret and

should be used except in cases of emergency, as it is found it is better to bring the turret to a low speed when approaching the target and before throwing the controller to the "off" position than to attempt a sudden stop from high speed. The braking effect of the motors running as generators is indicated by the reversal of the direction in which the ammeter pointers swing.

In addition to the wide segments there are narrow ones, 10, 12, 14, and 16, which make contact at their respective fingers a little before, and break a little after, the segments which they connect. They introduce resistances into the armature circuit known as auxiliary resistances, the object of which is to decrease the volume of current at the first instant of contact and also reduce the amount at the final break. This diminishes sparking at all points.

All leads are held in the contacts inside the controller by screw connections and are led out at the back of the case where they are protected by a box with a removable cover. Below the controller a connector is inserted in each wire, except those terminating at the local switchboard, to facilitate testing and repairs. The local switch-board carries the circuit breaker, two double-pole armature and two field switches, two discharge resistances, and one ammeter double-shunt. One single-pole circuit breaker is in the positive side of the generator armature circuit near the controller, and is operated by two rods extending through the turret platform; one closes the circuit breaker when pushed down, but is returned to its position by a spring when pressure is removed. The second rod when pushed down opens the circuit breaker and is similarly returned to position by a spring. The shunts consist of two resistances mounted end to end on a fiber base, the current entering between them, dividing, and passing to the separate armature switches for the individual motors. They are used in connection with ammeters located on the mantlet plate beside the controller.

The ammeters are zero center reading, necessary because they are in the armature circuit where the direction of the current is reversed by the controller. The leads between the shunts and the ammeters consist of flexible cord, and *each must be used with the ammeter with which it has been calibrated.* Below the shunt are shown two double-pole armature switches for each

motor, and under them are two smaller field switches with a special contact for the field discharge resistances located near them. Each of these latter switches controls the field of one

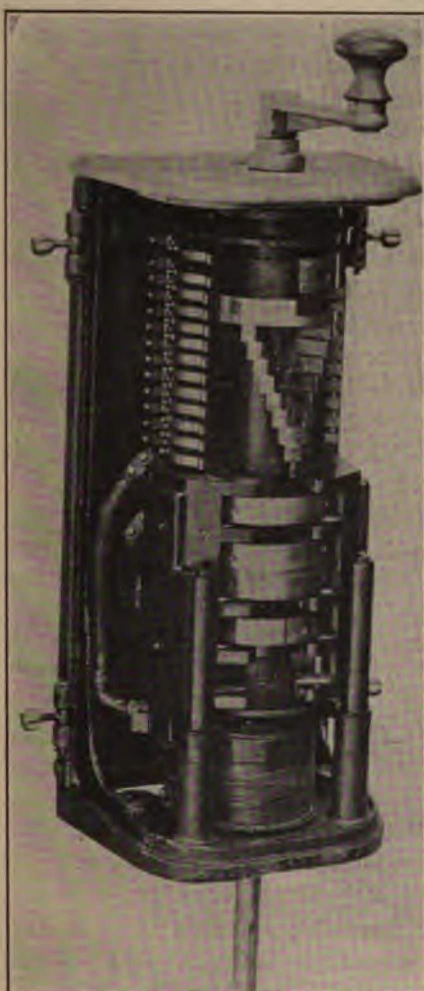


FIG. 146.—Latest design of controller for turret turning. P-10 type.

tor, the main field current dividing before entering them. One the resistances is connected between the long clips of each of field switches, and its office is to supply a path for the dis-

charge of the field when the switch is opened and prevent the arc of self-induction. This is accomplished by causing the blades which connect to the motor field terminals to come in contact with the long clips just before breaking the feeding circuit; the field discharge then passes through the resistance. When the switch is closed the blades must be forced in to be free of the long clips or a current will pass through the discharge resistance which will burn it out.

If it is desired to run with only one motor the armature switch of the other can be opened.

The field excitation for both generator and motors comes from the positive side of the power bus-bars entering the generator and motor field switch; both fields are, therefore, separately excited. The inner blade connects to the positive bus-bars and feeds both generator and motor fields.

The middle blade is in the return motor field circuit and has an extra set of clips above which connect with a resistance to take the discharge of the motor fields in a similar way to the field switches for the turret.

The outer blade connects on the upper side with the generator field rheostat connecting to the controller and at the lower side to the bus-wire on the back of the main switch-board, and thence through the generator shunt-field switch to the generator field.

The P-10 Type of Controller.

The controller is shown in Fig. 146 and is much the same in construction as the P-2 except in the arrangement of its fingers and contacts.

In Fig. 147 is shown a diagram of the system of connections for operating the turrets of the *Connecticut*.

In tracing the diagram which shows the present method of connections for energizing and controlling the two motors used for each turret of the balanced type, whether 12-inch or 8-inch, the connections will be seen to be separable into three sections: The starting panel for starting the motor-generator, the motor connections, and the controller connections.

The Starting Panel.—The starting panel controls two sets of connections by two switches, a motor switch for starting the motor of the motor-generator, shown to the left, and an arma-

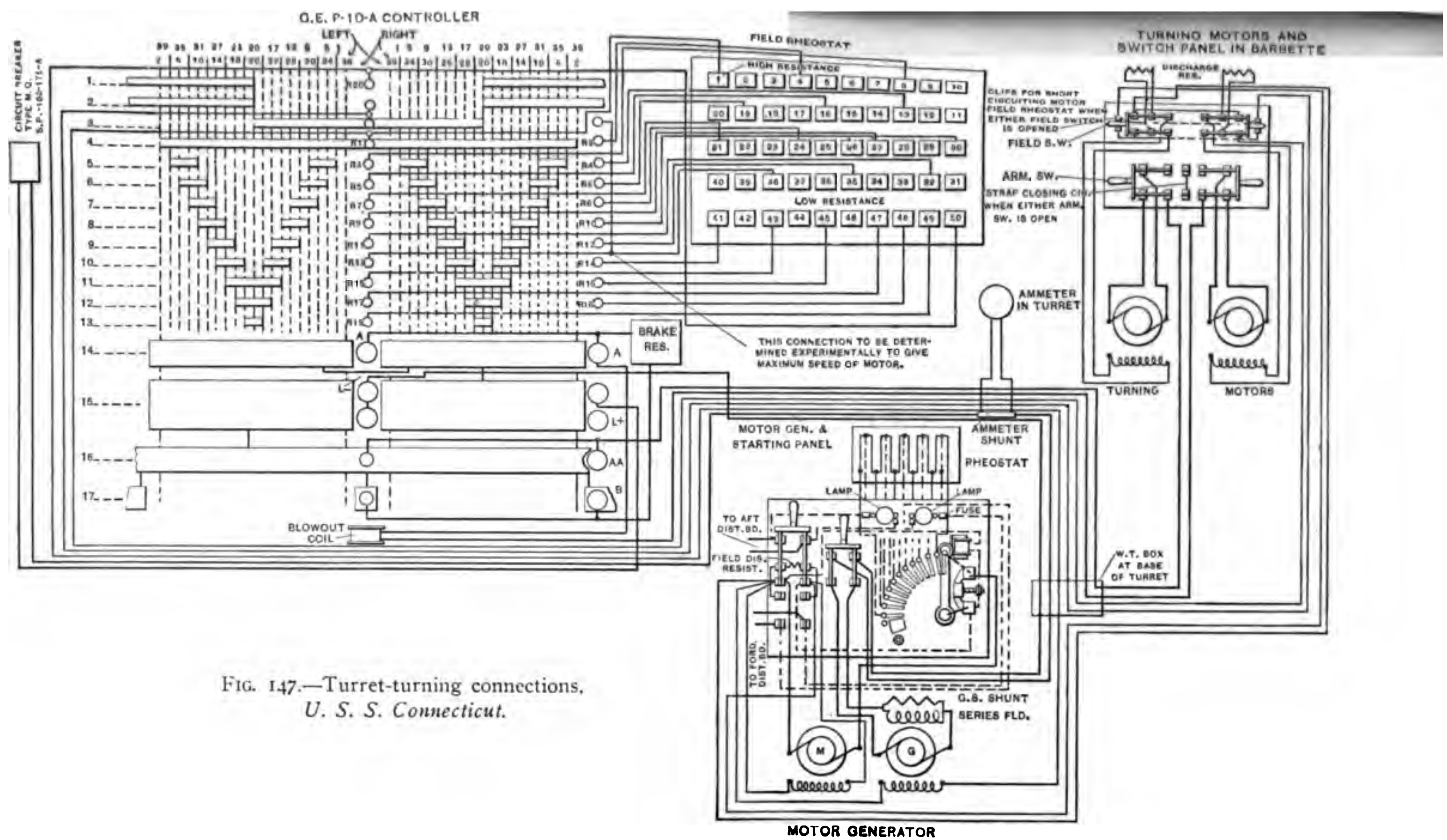


FIG. 147.—Turret-turning connections.
U. S. S. Connecticut.

ture switch, for connecting the armature terminals of the dynamo of the motor-generator to the controller and the two turret motors; this switch is shown to the right of the former switch.

The motor switch is a double-pole, double-throw knife switch, hinged, and making two sets of contacts on two blocks; when this switch is thrown up the supply is received from the ship's after-distribution board; when it is thrown down, the supply comes from the forward-distribution board.

The upper contacts of the upper throw, and lower of the lower throw, are short-circuited through a high resistance to break the spark; as shown by the dotted line, lamp, and fuses. These contacts supply five circuits, as shown:

I. The circuit for the starting of the motor-generator, as the left blade of the switch has its hinge-block connected directly to one brush of the motor of the motor-generator, while the hinge-block of the right blade connects (heavy dotted line) to the hinge of the lever of the starting rheostat. This starting rheostat is of the general no-voltage-release type, the resistance connections, and lever spring for throwing the lever to the "off" position being shown. No overload device is contained, overload being provided for in the circuit-breaker which closes the supply line at the after (or forward) distribution board.

II. A circuit running to the switch of the turret-turning motors to supply their fields.

III. A circuit supplying the fields of the motor of the motor-generator, this circuit being merely a connection to the hinge of each switch blade and hence keeping this motor's fields at constant, unvarying potential.

IV. A circuit supplying the shunt field of the dynamo of the motor-generator but connected through the variable resistance effected by the controller and by which the field of the motor-generator dynamo is varied at will, and consequently the potential at the terminals of its armature.

V. The circuit of the magnet coils of the no-voltage-release magnet.

The motor-generator switch is merely for closing the connections of the dynamo terminals of the motor-generator with the controller, one lead having an ammeter connected in, the ammeter being located in the turret.

The Motor Connections.

The motor armature connections from the controller lead to a double-pole, double-throw knife switch for each motor which, when closed, as shown in the diagram, *connect the motors in series with each other, which is the method of connection intended for usual operation of the motors;* should it be desired to operate but one motor to turn the turret—which is sometimes practicable—the switch of the motor which is to be cut out is thrown to close the contacts of the " strap-closing circuit when either armature circuit is open "; either motor can be thus used as desired. *There is no device for operating the two motors in parallel. Either or both can be used at will, but if both are used they are always in series with each other.*

[NOTE 24.—Apart from the improvement of the gear train between the motor and the turret, the foregoing shows the two great improvements between the systems of the *Brooklyn* and *Kearsarge* and the systems of recent date, the use of the motor-generator, and the connection of the motors in series.

Motor Generator.—The whole duty of one generator is required for the operation of a Leonard system of control for one set of motors and that generator must also have an especial device for reducing the series field. For a six turret ship six generators would be required for turret-turning alone, not to mention others in case the Leonard system is used for gun elevating.

This is now met by installing motor-generators for the Leonard control systems, the motors taking energy directly from the bus-bars of the main switchboard. The generator field connections of the motor-generator can then be made adjustable to the system of control and the main generators in the dynamo room can be large units, can feed their total output to the bus-bars, can be kept to their normal machine connections, and can mutually assist by paralleling. Furthermore, it lies within the design of the motor-generator to supply to the motor its available overload capacity of at least 50 per cent in emergency, the effect of overload drive falling to the dynamos of the motor-generator, but less serious in its consequences when distributed to the bus-bars than if for single main generators of the dynamo room.

Series Connection.—The effect of connecting two motors in series is that, while each will be able to take its full load current, the voltage impressed at the terminals of each motor will be only half that of the supply line—half the voltage the motor would receive if it were connected singly to the line, or in parallel with the other motor—the effect of the half voltage being to practically halve the motor speed, and at the same time to develop a large torque at the reduced speed. This large torque at low speed is

well illustrated by the curves of (Fig. 148) constructed from experiments made by Prof. C. P. Steinmetz on railway motors when operated in series and in parallel. Comparing the torque for a speed of 100 r. p. m. when in series, it will be seen that equal torque requires a speed of over 700 r. p. m. when the two motors are connected in parallel; applied to a turret it illustrates that desirable slow speed with good driving torque is attainable by connecting the motors in series. A paralleling device is not necessary as sufficiently higher rates of speed can be provided for in the controller by weakening the motor fields.

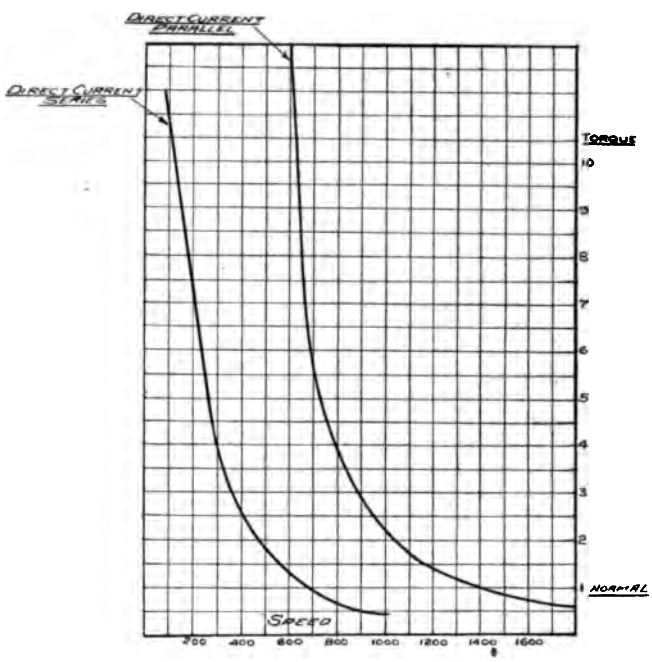


FIG. 148.—Curves of torque and speed for series and parallel connection of two motors.

In the tests of the *Brooklyn* and of the *Kearsarge* and *Kentucky* the factor of high rate of speed for extreme train predominated; this is shown in the specifications and the test results of 70 seconds for complete train in the former case and 58 for complete circle (360 degrees) in the latter as calculated from an extreme train in 53.4 second. The *Brooklyn's* forward turret was started and stopped 37 times in the peripheral distance of one inch, but the test was made rather as a comparison with the steam driven turrets; in the case of the *Kearsarge* the slowest practicable speed was about 30 degrees of arc per minute. Present specifications require a maximum training speed of only 100 degrees of arc per minute, a reduction of 3.6 : 1 as compared with the *Kearsarge* tests, but they also require a

minimum training speed of six degrees per minute or one-fifth of that formerly attained.

The reduction of speed, fineness and steadiness of slow control, is necessitated for better fire control and the increased ranges of target.]

The motor field connections have a double-pole, single-throw, knife field switch installed on the board with the armature switch. The hinges of the switch blades of each motor connect its field. When closed on the outer contacts one blade is connected in circuit to the motor switch of the motor-generator starting panel; the current comes out by the other blade (for the left motor) to the opposite contact, it is connected back to the opposite pole of the motor switch on the motor-generator starting panel through two "clips for short-circuiting motor field rheostat when either field switch is opened," the clips being connected; in this connection for the right motor a connection is made to the controller for the purpose of introducing a resistance in the motor field, as later explained. The short-circuiting clips are used when only one motor is operated. A pair of contacts on each switch introduce a high resistance across the field terminals. The contacts 3 to 13, inclusive, are the only ones connected to resistances, excepting that the low resistance No. 50 is switched in on contact 1 at position 20.

The Controller Connections.—The connection from the left-hand side of the motor-generator armature switch passes to and through the water-tight box in the turret base to the circuit-breaker, the ammeter being installed on this lead. From the circuit-breaker the lead runs to one set of two fingers, the two connected, of contact 15; this is the positive lead to the controller from the armature of the motor-generator. The negative lead goes via the water-tight box in the turret base direct to the other two fingers, connected together, of contact 15. Hence, the two pairs of fingers of contact 15 are the positive and negative terminals of the controller cylinder for the turret-motor armature leads.

The different functions of the controller are traced as follows:

I. *Connection of Armature of Dynamo or Motor-Generator to Turret-Motor Armatures.* II. *Reversing Switch.*

As has been pointed out the motor-armature switches connect the motor armatures in series.

The two fingers of contact 14 are connected together, and circuit is made to and through the blow-out coil and thence to the armature switch of the right-hand motor; thence through its armature back to the other pole of its switch; to the switch of the left-hand motor, through its armature; back to its switch, and thence to the fingers of contact 16. Contact 16 is a continuous conductor and is connected to the left part of contact 15. Hence, if the controller is moved to any position on the right, the current can flow from the right part of contact 15 through its connection to the contacts of 14 (connected together); thence to the motors and back to the left part of contact 15, which is the negative terminal of the controller cylinder; if the controller be moved to the left the direction of the current will be reversed since the right part of contact 15 will connect with the negative terminal of the controller. This set of connections, therefore, accomplishes the action of a reversing switch also.

III. *Varying the Voltage of the Field of the Motor-Generator Dynamo.*

The connection for the shunt field of the dynamo is a circuit from the hinge of the motor switch of the motor-generator starting panel to and through the dynamo field; thence through the water-tight box in the turret base, to a connection for the finger of contact 1, this being connected to $R50$; the return circuit is through the resistances to $R1$, which connects to the left finger of contact 4, the finger touching this contact for all positions of the controller; from the finger of block 4 a circuit leads by way of the water-tight box in the turret base to the clips of the turret-motor field switch and thus forms the connection for the other leg.

If the controller is moved to the right block 4 makes contact on the finger $R2$, then on $R4$ and so on, each time cutting resistance out of the dynamo-field circuit, increasing its armature voltage, and consequently the speed of the motors, as all the contacts, 4 to 13, inclusive, are connected together. This continues until position 20 is reached, when contact 3, electrically connected to 4, comes in contact with the finger above $R2$ (not marked) making a connection by which all the resistances are cut

out and the dynamo field has no resistance in circuit; the dynamo armature is, therefore, developing its greatest voltage, and the turret motors their *maximum speed for constant excitation.*

IV. *Varying the Field of the Turret Motors.*

A lead from the motor switch of the motor-generator starting rheostat leads to the turret-motor field switch for each motor and through the clips back to the negative pole of that switch; hence the motor fields are excited at the full voltage of the supply line as long as this condition remains undisturbed. On the field switch of the right motor is connected a circuit which leads via the water-tight box in the turret base to the connection to contact 4, and from the clip of the same switch leads a connection, also via the box in the turret base, to a connection between the fingers of contact 2 and contact 3. When, therefore, contact 2 has made contact with its finger the constant excitation from the starting panel is short-circuited, but the motor fields are not deprived of current because contact 1, electrically connected to 2, comes in touch with finger *R*20 and the motor field receives current through the high resistances as determined by the contacts 4 (and 3) to 13, inclusive; being so arranged as to cut in resistance as the controller cylinder is moved on, the motor fields are further weakened, causing the motors to speed up.

To prevent an excessive resistance from being cut into the motor fields, the short-circuit in passing from position 20 to position 21 is made adjustable to that desired and the resistances numbered 49 and 50 are used, being low and but little in excess of that of the former line for constant excitation.

V. *Action at the "Off" Position* (Fig. 147).

From the finger of contact 14 is a circuit through the brake rheostat leading to the two fingers of contacts 17, which, in this position, cover their fingers. Contact 17 is connected with 16, from which a circuit leads through the armatures of both turret motors as described in I above, hence this forms a short-circuit and one of low resistance; if, after the controller is in this "off" position, the turret motor armatures should continue to revolve they would generate an electro-motive force through this

low-resistance circuit, their fields being still separately excited, which will exert a strong counter effort and stop the motors and turret.

VI. *Résumé of Important Positions* (Fig. 147).

"Off" Position.—In this position a short-circuit is formed through the brake rheostat and motor-armature circuits, producing a strong effort to stop the turret should the motors continue to revolve through inertia. The motor fields remain excited at supply line potential.

Position 1.—All resistance is cut in the dynamo field circuit. Motor fields are excited as before.

Position 9.—Resistances Nos. 50 to 27 remain in the dynamo field circuit. Motor fields are excited as before.

Position 19.—Resistances No. 50 and No. 49 remain in the dynamo field circuit. Motor fields are excited as before.

Position 20.—No resistance remains in the dynamo field circuit, and the motors are at their maximum speed at constant excitation. The motor fields remain excited as before.

Position 21.—No resistance is in the dynamo field circuit. Resistances Nos. 49 and 50 have been cut into the motor field circuit, weakening the field, the motor, therefore, speeds up.

Position 26.—No resistance is in dynamo field circuit. Resistances No. 41 to No. 50 have been cut into the motor field circuit, and the motor attains higher speed than in positions preceding.

Remaining Positions.—The connections for the remaining resistances, 1 to 41, inclusive, to be gradually cut into the motor field circuit to still further increase the speed are determined by experiment; the dynamo field being without any resistance in circuit.

CHAPTER VIII.

MOTORS (Continued).

Ammunition Hoist Motors.

There are two varieties of ammunition hoists: that in which a whip is used for hoisting the car or weight; and that in which an endless chain is operated by the motor, the weights being attached to convenient parts of the chain. Officially the term "Whip Ammunition Hoist" is restricted to 6-pounder and like hoists. On board ship the ammunition hoists are generally designated by the caliber of the gun to be served; as 12-inch hoist, 8-inch hoist, 6-inch hoist, etc.

13-Inch and 12-Inch Hoists.

Each gun has its own separate hoist.

The whip, a flexible steel-wire rope, is attached to the ammunition car; it passes over guide sheaves at the upper end of the ammunition track and leads down to a drum which is geared to the motor.

The Motor.—One type of shunt motor, installed in the *Kearsarge* class, is shown in Fig. 149. It is of the enclosed armored type, having its field excited at 80 volts. It gives a rated output of 20 horsepower, for a rated input of 110 amperes at 160 volts, operating at a speed of 350 r. p. m. The motor is similar in constructional details to the turret motor (Fig. 143). Fig. 149 also shows the gear case, brake wheel, and the solenoid brake for this type of motor (see Fig. 140).

The latest design has an output of 55 horsepower at 125 volts for a speed of 400 r. p. m., this large output being necessitated by the additional power required for operating the automatic doors

in the turret. The drum is also made larger and scored t
receive the fall of the whip, which leads over the pulleys and i
attached to the ammunition car at its fall end. The motor fo

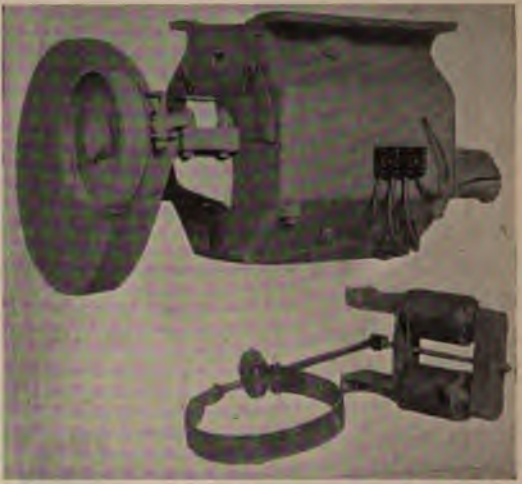


FIG. 149.—13-inch ammunition hoist motor with solenoid brake.

this design is similar to that of Fig. 149, but has a more efficie
type of brake, known as the disc type.

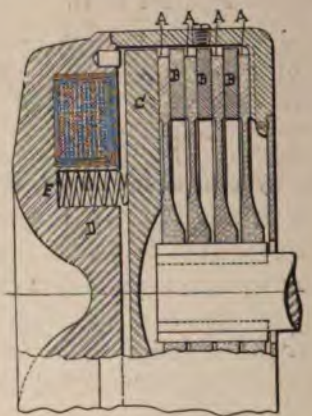


FIG. 150.—Disc brake. Half cross-section.

The Disc Brake.—The type is shown in half cross-section
Fig. 150.

The discs, *A*, are of bronze, and are slipped over two feathers on the shaft, the latter diametrically opposite; these discs, therefore, run with the shaft.

The collar rings, *B*, are of cast iron and are slipped in, free to move in the direction of the shaft, on keys or lugs on the inner periphery of the enclosing casting, which keys prevent the collar

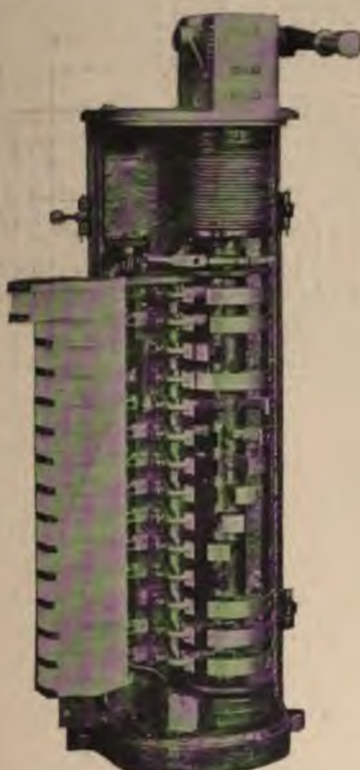


FIG. 151.—Controller for 8-inch ammunition hoist.

rings from turning. The armature, *C*, of the electro-magnet, *D*, also slips on over the shaft feathers but is free to move in the direction of the shaft, and, when no current is passing, is held off from the magnet by eight springs, *E*.

As long as the controller is operating in other than the "off" position, the magnet, *D*, attracts the armature *C* and hence holds the brake released: At the "off" position the magnet releases

the armature, *C*, which presses a disc against one of the collar rings, *B*, and, as all these rings can move in the direction of the line of the shaft, all rings come into action and the friction brings

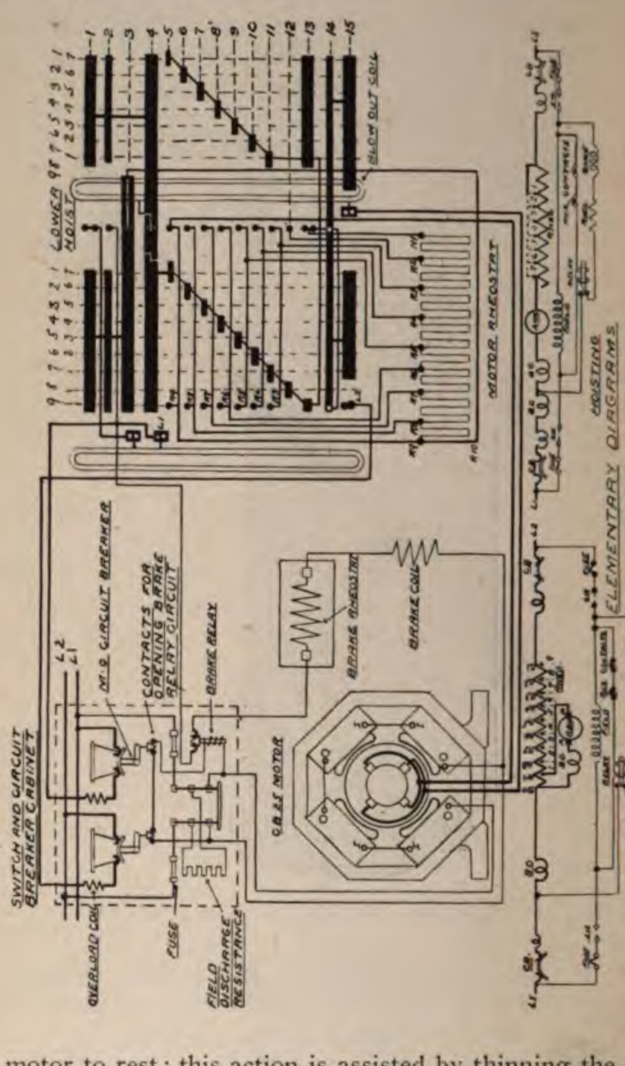


Fig. 152.—Connection diagram of ammunition hoist controller.

the motor to rest; this action is assisted by thinning the discs, *A* near the center, giving a spring effect. The discs being of bronze and the rings of cast iron ensures against "freezing" by corrosion.

Controller.—The type of *controller* used is that known as the B controller, designed to give an electrical braking effect by the dynamo action of the motor armature for the Day System of Control. The B-28 type for control of the 8-inch hoist motors is shown in Fig. 151. The B-44 type used with the 12-inch hoist motors is similar.

In this controller the lever is arranged to revolve the cylinder by means of bevel gears: To hoist the ammunition car the lever is raised; to lower, it is pushed down, thus following the direction in which the car is to be operated. There are seven hoisting and nine lowering speeds.

In tracing the controller and other connections shown in Fig. 152, the controller development being there shown for the "off" position, it will be noted that the leads to the motor are short-circuited through the blow-out coil, via R_{10}, Rg, and the finger of contact 5, giving the armature braking effect, should the inertia of the armature tend to continue its revolution when the controller is at the "off" position.

The office of various contacts are:

In Hoisting.—The contact 4 (side of diagram) being in contact with its finger moves over the contact with the positive side of the line, but, just before this, contact 16 closes circuit with its finger, hence the blow-out coil is ready to operate as soon as contact 4 closes with the line. At the position 1 (top of diagram) contact 11 throws in all resistance from R_8 to R_{10}, inclusive, and as the controller moves on to position 7, the resistance is gradually cut out until at position 7 the motor armature receives the full potential of the line. Contacts 1 and 2 serve to connect the line to the brake relay and, being in connection throughout the seven positions, the brake magnet is energized and its armature holds the brake released. Should the voltage fail the relay will open the brake circuit and set the brake.

In Lowering.—The first position of the controller has practically little resistance in circuit; the dynamo action occasioned by the weight of the car producing an electromotive force to control any rush of current, any farther motion of the car is afforded by the other eight positions. Stopping is effected by a quick movement to the "off" position, which sets the brake. In both cases, lowering and hoisting, the motor field is energized by separate excitation through connection to the main switch, which has a

high resistance shunt to protect the field circuit from self-induction. One leg of the brake circuit is tapped off the motor field circuit, the other connection of the brake relay leads to the controller.

Automatic Shutter Device.

The automatic shutters are installed to shut off the handling room from the loading space in the turrets, except for the short time that the ammunition car is passing up or down through the shutter opening. The opening and closing of the shutter are effected by the lengthening and shortening of the bights of the shutter-operating drum ropes.

The shutter-operating drums are driven from the ammunition-hoist drum shaft through spur gears, ratio 2 to 1, so that the shutter-operating drums make two revolutions for every revolution of the ammunition-hoist drum.

The complete cycle of events for a round trip, up and down, of the ammunition car are as follows: When the ammunition-hoist drum has made 2¼, and the shutter drum 4½, revolutions, the "leading" ropes on the latter enter the first spiral grooves; this occurs when the car is about 30 inches below the shutter opening, and the bights begin to shorten on the opening drum, and lengthen on the closing drum, the shutter begins to open and continues to open to approximately the vertical by the time the car has reached the middle of the shutter opening. As the car rises the ropes on the closing drum begin to shorten, closing the door by its own weight and the action of the drums, the closing beginning at the time the car is about 6 inches above the shutter.

In lowering the car the operations of the shutter are reversed, opening where it closed before and *vice versa*. Flexible steel tiller rope of ⅜-inch diameter, is used (75 feet for the opening and 65 feet for the closing).

8-Inch Hoists.

Except for differences due to weights to be handled the general arrangements for the 12-inch and 8-inch turrets are the same.

The motor is of the same general design, with similar controller, disc (or solenoid) brake on the commutator end, and with similar type of connections.

The motor output is 15 horsepower at 600 r. p. m. and 125 volts, each gun having its own motor service, as in the larger turrets.

The controller gives six hoisting and eight lowering speeds.

The motors handle automatic shutters in these turrets, as in the 12-inch, the general design being the same.

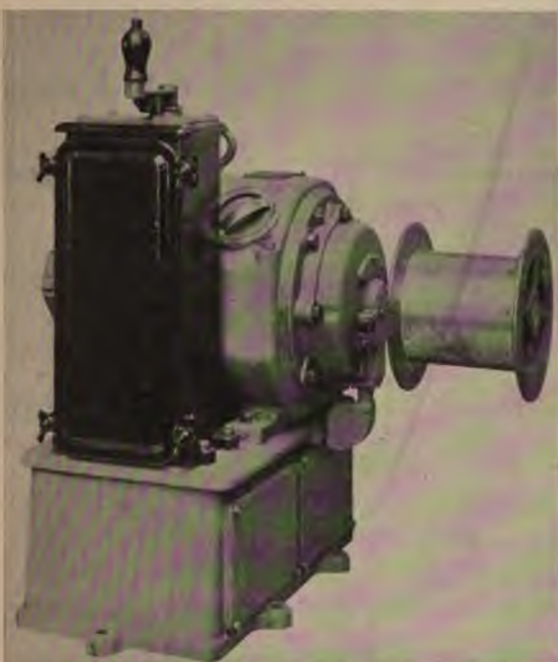


FIG. 153.—Whip hoist equipment.

Whip Ammunition Hoists.

These hoists are auxiliary to the ammunition supply from the chain ammunition hoists, and serve to deliver ammunition from the landing platform of the chain hoist on the berth, main, or upper deck to bridges or tops.

Their arrangement differs somewhat in different ships, but in the latest types the motor is mounted directly on the davit and connected by double reduction gears to a drum shaft carrying a 9-inch composition hoisting drum, over which passes the whip fall leading through the block at the davit head.

A complete whip-hoist motor assembly, as installed on the *Nebraska*, is shown in Fig. 153.

The motor is 3 horsepower, at 125 volts, speed 1100 r. p. m., and similar in construction to those used for the chain ammunition hoists and conveyors.

The controller is of the B-type, and its connections (Fig. 154) indicate in general a similarity in operation to that for the 12-inch hoists, but being smaller the cylinder is revolved by a simple handle on a lever, with thumb latch. The controller provides five speeds for hoisting and seven speeds for lowering, the con-

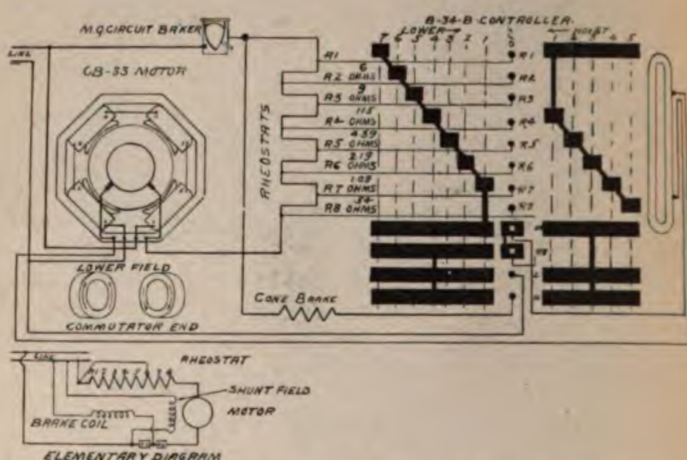


FIG. 154.—Connection diagram of whip hoist controller.

trol being so arranged that when lowering a heavy load the armature will generate current through the resistance, giving an electric brake (Day System). If the load is not heavy enough to overhaul, the armature will take current from the line. In the "off" position the armature is short-circuited, as in previous examples; the fields being separately excited, this produces a powerful braking effect.

The controller is mounted on a cast-iron base within which are mounted the rheostat and circuit breaker, which are accessible throught the water-tight covers to the side openings. The circuit breaker is so connected by a cam and lever that throwing the controller lever to the "off" position will set the circuit breaker.

Formerly there was a foot-brake attachment to hold the load should the current fail, but latest designs combine an electrically-operated cone brake, similar to that used with chain ammunition hoists, or a disc brake, similar to that used for the 12-inch and 8-inch hoists, size reduction being made for difference in the horsepower of the motor.

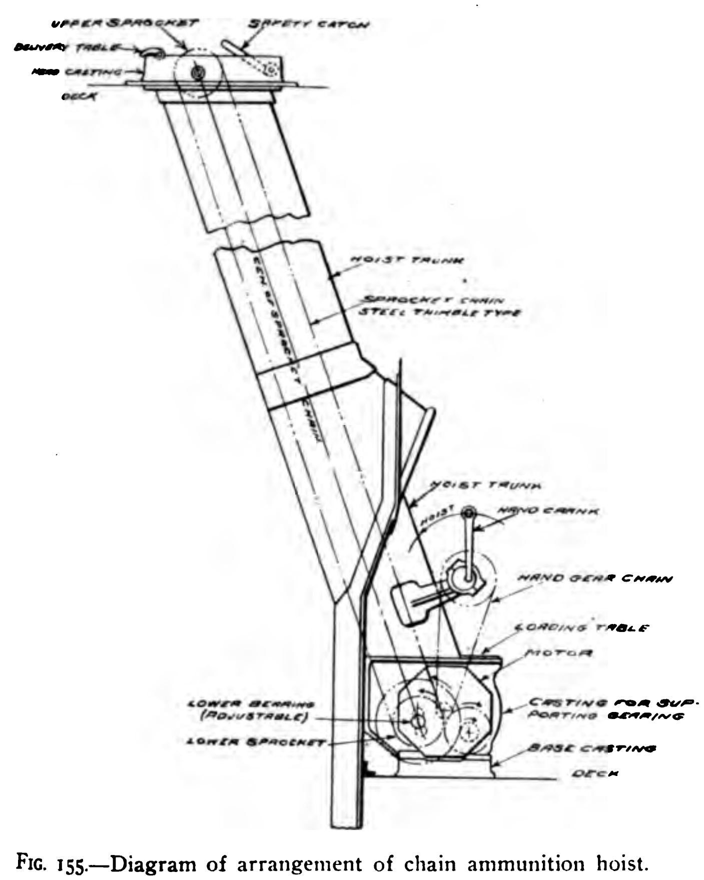


FIG. 155.—Diagram of arrangement of chain ammunition hoist.

Chain Ammunition Hoists.

All ammunition for the intermediate and secondary batteries is supplied by this type of hoist.

The main features of the general system are shown in Fig. 155. Each hoist is enclosed in a water-tight trunk. At the top the

trunk terminates in a composition deck casting fitted with a water-tight cover. There is a hinged delivery table on one side of this casting on which the ammunition is received. To prevent the ammunition from falling back into the trunk a safety catch closes after the passage of each carriage. At the bottom of the trunk is a flanged-plate loading table with the front of the trunk omitted; the space thus formed being blocked out with oak or teak and sheet steel to form a suitable recess for placing ammunition in the hoist. The driving gear is located beneath the loading table and consists of a motor, slip clutch, reduction gearing, and driving sprockets; all mounted on a single cast bed-plate.

The armature shaft of the motor is geared to a counter-shaft, having a pinion on the outer end which engages a gear on a shaft carrying the two lower sprocket wheels. Two continuous chain belts pass over these sprockets, and thence run over two similar sprockets in the deck casting at the delivery end of the hoist. To these two chains carriages are attached at convenient intervals for the size of ammunition boxes that are to be hoisted. The two bearings of the shaft for the lower sprockets can be moved along the arc of a circle, thus permitting adjustment for stretch and wear in the chain. The adjustment is made by adjusting screws which move the bearing as desired.

To prevent overhauling by loads and running the hoist backwards a pawl is fitted at the upper end which permits the carriage to pass up, but will catch and hold it if it starts backwards; in lowering, the pawl can be secured by a pin to allow reverse action of the chain.

A hand gear with sprocket is provided for operating the hoist when the motor is not available.

Some modification of the foregoing arrangement is necessary for especial cases: In one case the motor and operating gear are located on the berth deck while the loading table is in the hold; in another, the motor is on the upper platform, while the loading table is in the hold; the chains pass over two sprockets geared to the motors as usually; each chain is held in place by two idle sprockets, one above and one below the driving sprocket.

The number of carriages used varies from 12 for ammunition for the secondary battery to eight for the intermediate battery.

The motor is shown in Fig. 156, and follows the general line of construction for enclosed, water-tight, armored, shunt-wound, motors of which that for the turrets is the type.

The output is usually 3 horsepower at 125 volts, and having a speed of 400 r. p. m. The motor is 4-pole.

Controlling Panel.—The controlling panel shown in Fig. 157 is a form of starting rheostat generally used with motors having an output of 3 horsepower or greater, as for chain hoists and

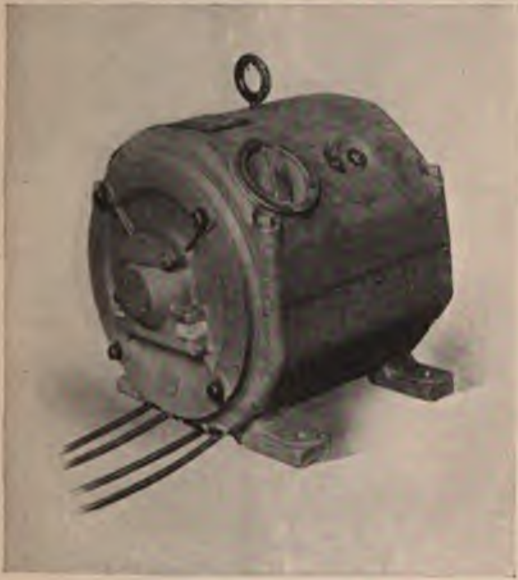


FIG. 156.—Motor for chain ammunition hoist.

conveyors. These hoists and conveyors being intended to run at a continuous speed a starting rheostat type is all that is necessary.

The panel consists of a slate base upon which are mounted spring clips for the main line fuses (no-arc, or enclosed, variety); an overload circuit breaker, used as a switch on one leg of the circuit; a single-pole main switch to close the other leg of the circuit; a double-throw, double-pole field switch, for reversing the motor; a starting lever; and starting resistances mounted on the back of the slate.

Attached to the starting lever and shown under the circuit breaker is a no-voltage release magnet.

Two extra terminals are fitted at the top of the panel for connecting in a safety switch, but they are not utilized in ship practice; this is shown in the connection diagram by the connection between the contacts, *S*.

The connections are shown in Fig. 158.

The lever is so arranged that as it is moved forward to the starting blocks connected to the resistance a bell crank and link

FIG. 157.—Controlling panel, U. S. type, Form C.

closes the circuit breaker, one pole of which is connected through the coil of the overload release magnet to the brass contact *H*. Current from *H* energizes one pole of the field for each throw of the switch. Current also passes from *H* through the lever to the contact *J* of the starting section of the panel and also by the "retaining" contact *K*, of the no-voltage release magnet by means of the push button. In starting, should the lever be moved too fast over the blocks the overload release magnet will attract its armature and trip the catch of the circuit breaker, which is

permitted by the arrangement of the bell crank and link connection to the lever, as the lever reaches the first blocks; that is, the lever closes the circuit breaker to its catch, but on reaching the first blocks no longer operates to keep the circuit breaker closed or interfere with its springing open. The no-voltage release operates in the usual way to release the lever. When the lever springs back against its stop it automatically opens the circuit breaker connection, thus cutting off all line connection to the lever and motor field, the motor field receiving its current through the contact *H*, and the main switch. Since this circuit is closed on closing the circuit breaker, and before the lever reaches the

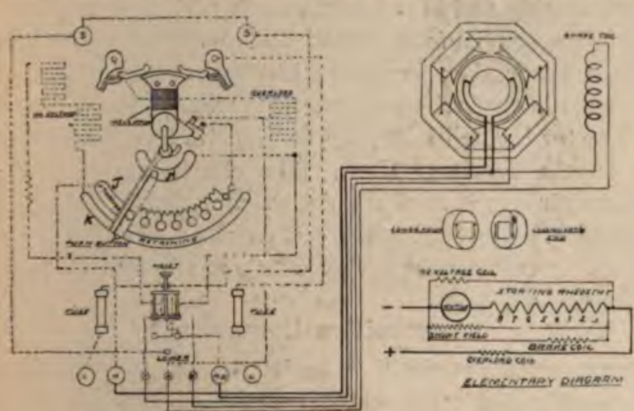


FIG. 158.—Connection diagram of chain ammunition hoist.

blocks of the starting section *the field will be energized before the armature can receive current and will be broken, by the return of the lever, after the armature current has ceased.*

The brake coil is connected to the last armature block and through the binding posts marked *B* one leg connecting to the main switch; this circuit is therefore energized through the resistance to hold the brake released as long as the armature is receiving current, and the brake is set as soon as the lever moves off (to the left) the starting blocks.

The Brake.—The *disc brake,* when used, is a form of that shown in Fig. 150, modified to suit the reduced power of the motor.

The *cone brake* operates on a similar principle to the disc brake of Fig. 150, and is attached to the commutator end of the motor

shaft. The brake consists of two parts: the inner, which is attached to the motor shaft, and which has a machined cone surface; the outer, which contains the brake coil and six releasing springs, and which is attached to the bed of the motor.

The magnet armature plate is of steel and is held from rotating by two pins sliding in slots in the inner casting and keyed to the shaft with a sliding fit. The slide next to the motor is recessed at the center to transfer the friction to the periphery.

The magnet armature is attracted when current passes in the coils releasing contact of the cone with the surface of the armature plate. The cone is of cast brass turned to fit the surface of the inner casting and keyed to the shaft with a sliding fit.

The brake coil is form-wound and insulated with varnished cambric and tape, then wrapped with copper ribbon. It is placed in the recess in the brake magnet and surrounded with type metal.

Each motor is fitted with a mechanical friction overload release clutch on the armature shaft. The clutch is designed to be within the pinion; it is of the double-cone, balanced-clutch type, and set to slip with about 50 per cent overload. The cones are held in place by a coiled steel spring which is adjusted by jam nuts.

Ammunition Conveyors.

Conveyors are practically a horizontal modification of chain-hoist movable platforms which transfer ammunition along an ammunition passage and usually to the chain hoists. There are four on board of the *Connecticut,* two 80 feet long and two 68 feet long; they are designed for a load of about 3000 pounds and operate at a speed of 100 feet per minute when the motor is running at 500 r. p. m.

The movable platform, or apron, is mounted in an especially-designed angle iron framework and consists of a series of stamped galvanized sheet-steel plates, fitted with lugs bolted to the apron sections, which lugs form a sprocket chain. The lugs are fitted with rollers having brass bushings, which operate on the upper part of the angle iron frame. Flat steel strips, riveted to the angle iron guides, limit any transverse motion; roller apron guides are placed at intervals of about 4½ feet to prevent sagging and friction in operation.

The apron is driven by two sprocket wheels, one at each end of a shaft, which mesh in the links of the sprocket chain. This

shaft is direct-connected through a series of gearing with the necessary shafts, bearings, and clutches, to the motor shaft. The sprockets at the loading end are provided with a device for taking up stretch in the chain. The frame is provided with tables at the loading end and opposite the chain hoist; when the loading end table comes into interference with closing or opening a water-tight door, part of the table automatically swings with the door.

The motor is of the same design as that for the chain ammunition hoists (Fig. 156), but has a capacity of 4 horsepower, at 125 volts, and a speed of 500 r. p. m.

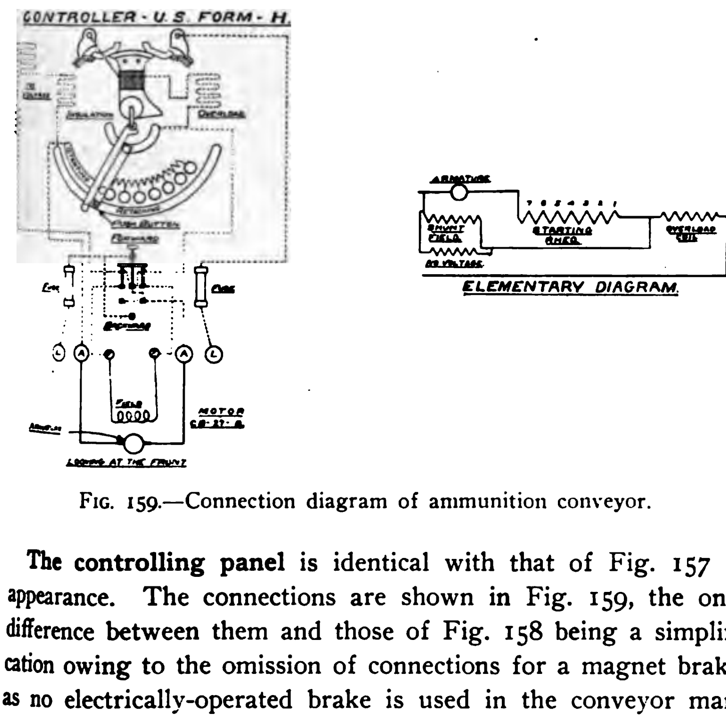


FIG. 159.—Connection diagram of ammunition conveyor.

The controlling panel is identical with that of Fig. 157 in appearance. The connections are shown in Fig. 159, the only difference between them and those of Fig. 158 being a simplification owing to the omission of connections for a magnet brake, as no electrically-operated brake is used in the conveyor management.

A mechanical friction release clutch meshes with the motor pinion and is of a lighter design than that used with chain hoists, but is also of the double-balanced, cone-clutch type, slipping at 50 per cent overload, the clutch pressure being applied by a coiled steel spring set up with jam nuts.

Gun Elevating Motors.

Heretofore a 2½ horsepower series motor has been installed for this service, but a shunt motor of 4 horsepower is now employed, which is fed from a motor generator, upon a simplified arrangement of the Ward-Leonard system. Each gun has its separate motor.

The motor is similar to that used with chain hoists. That for the 12-inch turrets is 4-pole, of 8-horsepower, with a speed of 420 r. p. m.; that for the 8-inch turrets is 2-pole, of 5-horsepower, with a speed of 540 r. p. m.

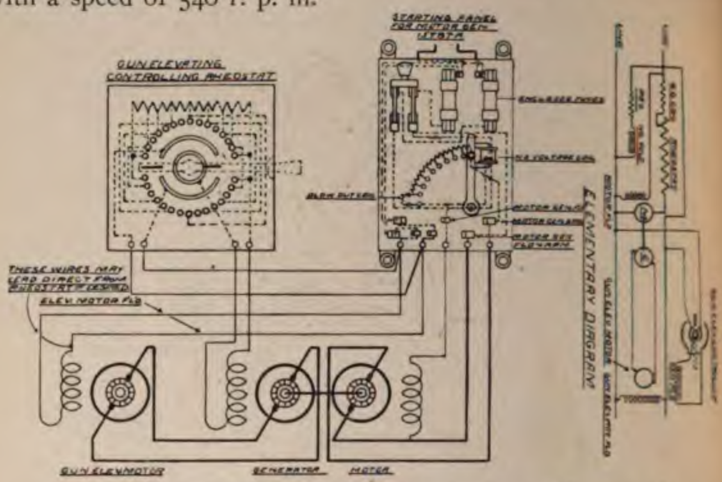


FIG. 160.—Connections of gun elevating controlling panel.

The connections are shown in Fig. 160.

There is no circuit breaker in the elevating motor circuit, the only overload safety device being the overload cut-out on the motor-generator panel.

The controller, or controlling rheostat, is located under the gun-pointer's sighting hood secured to a bracket which is part of the gun-sight bracket. The arrangement of the controller is to control the speed of the motor by the usual process of varying the potential of the generator field; *but reversal is accomplished by reversing the direction of the current in the generator field,* the connections between the elevating motor terminals and the generator terminals remaining fixed and direct.

The arrangement of connections is the same for both 12-inch and 8-inch turrets.

Rammer Motors.

Each 12-inch and 8-inch turret gun is equipped with an electrically-operated rammer.

The motor for the rammer service of the 12-inch guns is 4-pole, of 10-horsepower, speed 1000 r. p. m. It is series-wound and is located on the operating floor of the turret, being connected directly by gears to the rammer mechanism and driving through an overload friction clutch.

The motor for the rammer service of the 8-inch guns is similar to that for the 12-inch guns, and is shown in Fig. 161.

FIG. 161.—Rammer motor. Series wound.

It is 4-pole, having an output of 3½ horsepower, a speed of 750 r. p. m., and is series-wound. The motor is located in the base of the rammer and drives the rammer mechanism by a Morse silent chain.

Controller.—The type of controller used for both types of rammer motors is known as the R-type, its general characteristics being the control of the terminal voltage from the line for the regulation of series motors, both the field and armature current being broken at the "off" position. The type is that familiarly known in trolley service.

The actual apparatus is shown in Fig. 162 of which the lower, larger space is occupied by the rheostats. The apparatus is secured on top of the rammer, the controller cylinder lying horizontally. The lever is designed to be moved in the direction in which the rammer is to move, and the effect is secured by the

connections. The operating lever is so designed that when it is released in any position it will return to the "off" position and be locked in place.

The connections of the controller for the 8-inch rammer motor are shown in Fig. 163.

There are four positions for loading and but two for withdrawing the rammer, the connections for the latter operation providing for all practicable speed.

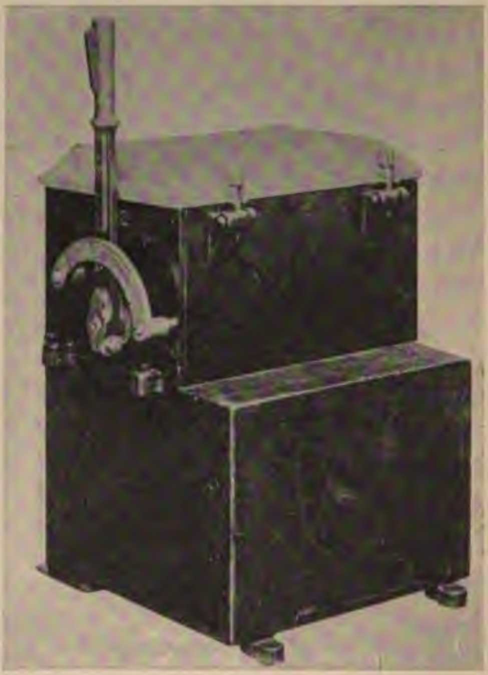


FIG. 162.—Controller for rammer motor.

Boat Crane Motors.

Two boat cranes are installed in latest ship designs, each having a separate motor for hoisting and for rotating. The cranes are designed for a maximum working load of 33,000 pounds, with a fiber stress of 7500 pounds per square inch, and to carry a test load of 66,000 pounds. Each crane has an overhang of 25 feet and a working circle of 300 degrees.

Fig. 164 shows the general arrangement and plan of a crane and the motor locations. The crane is of box section, built up of plate and angles, the weight being carried by a roller thrust bearing at the level of the main deck. There is a pivot steady bearing at the gun deck, and a steady bearing at the upper deck. Surrounding and rotating with the crane is a cast-steel platform on which are located the hoisting and rotating motors, with their accessories, and the hoisting drum. A circular rack is secured to the upper deck and meshes with a pinion of the rotating gear. The hoisting machinery is designed to hoist the working load of 33,000 pounds at a maximum speed of 25 feet per minute, and

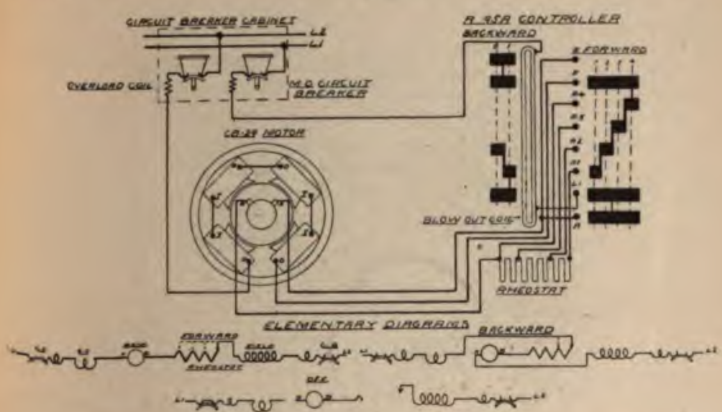


FIG. 163.—Connection diagram of 8-inch rammer controller.

upon removal of this load to hoist the empty hook at a speed of 60 feet per minute. The rotating machinery rotates the crane with the load of 33,000 pounds at a speed of one revolution per minute, the ship being heeled 10 degrees; it must have capacity to rotate while carrying the test load of 66,000 pounds, but at no specified speed.

For hoisting, the motor pinion meshes with the spur gear of the automatic mechanical brake on the end of the worm shaft. A triple-threaded worm engages the worm wheel, which is secured to the hoisting drum. The hoisting rope is a 1-inch (diameter) steel-wire rope leading directly from the drum over a guide sheave on the upper side of the crane structure to the sheaves in the crane head. The cranes have double sheaves with roller bearings.

For rotating, the pinion of the rotating motor meshes with a spur gear on the end of the horizontal worm shaft. The shaft of the worm wheel is vertical, and carries a pinion on the lower end

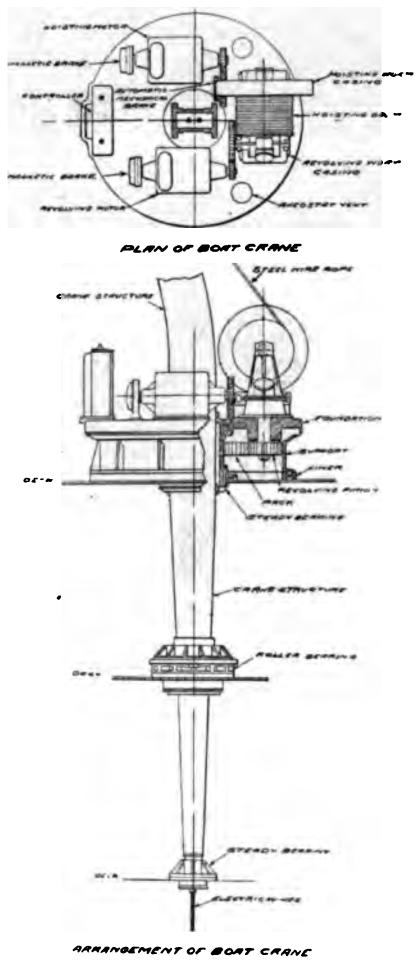


FIG. 164.

which meshes with the circular rack secured to the deck. The worm wheel has an internal mechanical overload disc-friction-release clutch.

The worms for both hoisting and rotating run in oil and have collar-thrust bearings.

The electric brake for both hoisting and rotating motors, is of the disc-type and similar in design to that shown in Fig. 150, the action being the same.

The motor used for the boat-crane service is shown in Fig. 165. It is series-wound, good starting torque for this class of service being important.

The hoisting motor is 4-pole, and has an output of 50 horsepower, a speed of 400 r. p. m., and is of the general iron-clad construction heretofore described.

The rotating motor is similar to the hoisting motor excepting that it has an output of 30 horsepower and a speed of 365 r. p. m.

Fig. 165.—Motor for boat cranes.

The controller is shown in Fig. 166. It is of the R-type and made double, combining the controller for the hoisting motor and that for the rotating motor, including the circuit breakers, in one assemblage. The controller is so located on the platform that the operator faces the load.

The connections of the controller to the motors is shown in Fig. 167. While essentially the usual controller method of starting rheostat, with accessories, the ingenious method of interconnection of but a single line supply will be noted; as shown, there are eight positions for both ahead and reversal action for both motors.

Automatic Mechanical Brake.—In addition to the electric brake on the hoisting motor an automatic mechanical brake is fitted on the worm shaft. It is of the disc-friction type, which is

set when any torsional strain, due to a load on the hoisting rope is put on the worm shaft. This is accomplished by a cam which forces the pinion along the axis of the worm shaft and compresses the discs; when the cam returns to its "off" position the discs are returned to their "off" position by the pressure of coil springs. *In hoisting* the brake is set by a rotation of the pinion, which is sufficient to cause the shaft to turn with the pinion, the ratchet being turned away from the pawls, the pawls being held

Fig. 166.—Controller for both motors of a boat crane.

off by a friction pin, which rubs on the side of the gear. *In lowering*, with no load on the crane, the friction of the worm, worm wheel, and drum bearings will cause a torque in the opposite direction to that caused in hoisting. The pinion will drive the worm shaft by the shoulder on the cam, the brake being in the released position, and the ratchet driving against the pawls, and, therefore, held by them against rotation; the composition discs are also held from rotating, but there being no lateral pressure there is no braking effect. Should there be a load on the crane, sufficiently to cause the gearing to overhaul or run faster than the

speed of the driving motor, there will be torque in the same direction as that of hoisting, proportionate to the load, and which determines the amount of lateral pressure on the discs. Should the motor be stopped the whole effect of the torque falls to the cam, which produces the necessary lateral pressure to hold the load stationary. The motor having been started again relieves the torsional strain on the cam; the speed of the motor then determines the torsional strain on the brake and, therefore, the descending speed of the crane load.

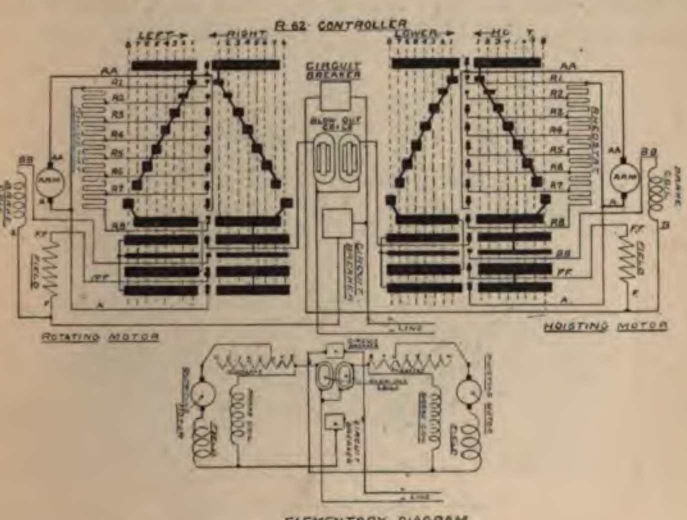


FIG. 167.—Connection diagram of boat crane controller.

Automatic Stop.—This consists of a trigger so installed that when the crane reaches nearly the extreme limit of its travel in either direction of rotation the trigger strikes a stop placed under the operating platform and trips the circuit breaker.

Deck Winch Motors.

For this type of service the series motor is most frequently used, it being usually considered that the electric and mechanical losses of the motor, including the load occasioned by the gears, is sufficient to guard against racing should the fall part or the motor be otherwise deprived of load.

A type in general use is the Superstructure, or Upper Deck

Winch, shown in Fig. 168; there is also a Main Deck Winch type. Fig. 168 does not entirely accord with the latest arrangements of the winch, as noted in this description, but conveys the idea of winch assemblage in general.

Superstructure, or Upper Deck Winches are single-speed, reversible, and capable of exerting a pull of 2200 pounds at a peripheral speed of 300 feet per minute. Upon a cast-iron base are mounted the bearing stands, motor, and controller, the base having sufficient bolt lugs for equal distribution of the strain on the deck. The bearing stands are cast iron, having bronze bearing linings lubricated by grease. The main shaft is 4½

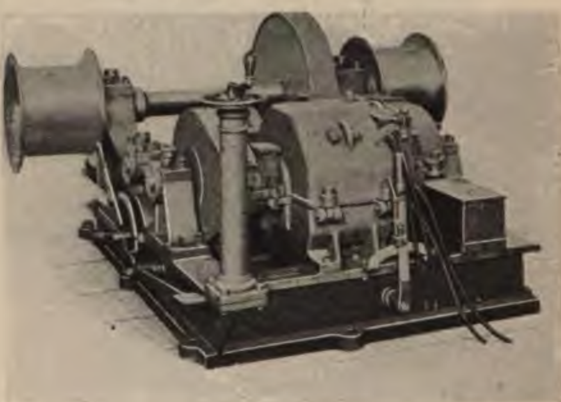


FIG. 168.—Upper deck winch.

inches in diameter, of forged steel; upon it are mounted two gypsy heads, 18 inches by 18 inches, and a band wheel to which the mechanical brake is applied; there is no electric brake. The friction band is a steel strap, lined with wood, having sufficient surface to hold the load when operated by the foot lever mounted on the side of the base. All gears are of cast steel except the motor pinions, which are of wrought steel. The pinion has 14 teeth and the gear 84 teeth, of 3 diametrical pitch and 4-inch face. The gears are enclosed in a cast-iron case which is divided in the horizontal plane. The resistance is contained in a water-tight enclosure, and is provided with a packed, removable cover.

The motor is 4-pole; of the armored, enclosed type of construction; is series-wound, has an output of 25 horsepower, and a speed of 350 r. p. m.

The controller is of the R-type and similar in construction to that for the boat cranes (Fig. 166) except that it is single instead of double.

The connections are shown in Fig. 169.

Main deck winches are reversible and have two speeds, the ratio between the fast and slow speed being 1 to 6. They exert a pull on the gypsy head of 13,200 pounds at a speed of 50 feet per minute, or of 22,000 pounds at 300 feet per minute. There are three bearing stands; two of these are arranged to carry the

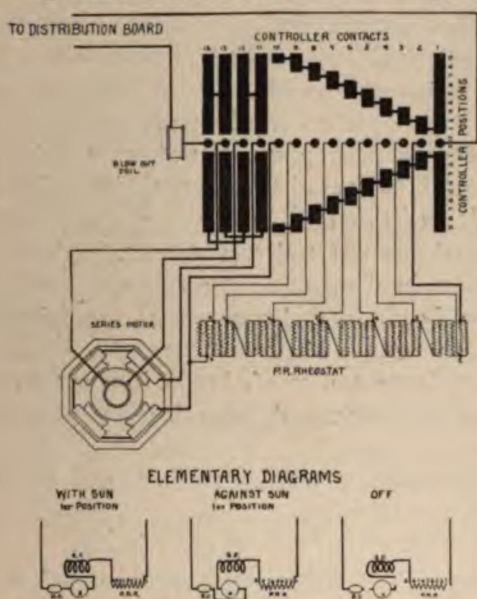


FIG. 169.—Connection diagram of controller for upper deck winch.

bearings of both the main and secondary shafts, this to secure proper alignment. The main shaft is of hammered steel and is 6½ inches in diameter. Upon each end of the main shaft are two gypsy heads, identical with those used in upper deck winches. Two pinions and a clutch are mounted upon the secondary shaft; the clutch is operated by a lever which is provided with spring lock and quadrant to avoid possibility of accident; the clutch is keyed to the shaft; the pinions run free. The change of speed ratio is effected by changing the position of the lever.

The motor, controller, mechanical brake, and foot lever are the same as in upper deck winch assembly.

Ventilation Motors.

Although usually considered as apparatus of larger size and designated as blowers, the general classification includes the portable fan of ¼ horsepower, and the bracket and desk fans, of ⅙ horsepower and 1/12 horsepower.

Blowers.—These include all fans requiring more than ¼ horsepower, the number and large variation in size being indicated in the table on page 256.

The general ventilation of the *Connecticut* is subdivided into 33 independent systems, rendering unnecessary the piercing of any of the principal water-tight bulkheads below the protective deck, reducing the number of automatic bulkhead valves, increasing the efficiency by the use of smaller and shorter lengths of piping, thereby reducing frictional resistance and weight. At 1-ounce pressure this ventilation system is designed to give a change of air as follows:

(*a*) Officers' quarters and crew spaces, berth deck, outside of casemate armor, in about 12 minutes.

(*b*) Officers' quarters and crew spaces, berth deck, within casemate armor, in about 4 minutes.

(*c*) Water-closets and crew's heads, in about 6 minutes.

(*d*) Storerooms in general, magazines and passages, in about 8 minutes.

(*e*) Engine-rooms, general workshop, and steering compartments, in about 2 minutes.

(*f*) Evaporator room, in about 2½ minutes.

(*g*) Air space over boilers, in about 1½ minutes.

(*h*) Dynamo rooms, in about ¾ of a minute.

The 33 systems are designated as sets in the following table, in which each set is designated by a serial number shown on a name plate on the ventilator assemblage installed in the ship. The table also shows some details of the motor as to number of poles, horsepower, range of speed, and whether open or enclosed; also the fan capacity in cubic feet per minute from manufacturers' tests.

The spaces ventilated by the foregoing sets are:

Set. No. 1.—To exhaust from water-closets, etc., on gun-deck forward of bulkhead 17; and from sick bay water-closet, isolation ward, and paint and oil-rooms on berth-deck forward of bulkhead 16.

Sets Nos. 2 and 3.—To exhaust from the forward dynamo-room.

Sets Nos. 4 and 5.—To exhaust from firemen's and servants' wash-rooms, and passages on berth-deck between bulkheads 40½ and 72. The discharge from these fans is used in ventilating the air space over the boiler-rooms.

Set No. 6.—To exhaust from the evaporator-room. The discharge is used for ventilating the air space over the boiler-rooms.

Sets Nos. 7 and 8.—To exhaust from officers' water-closets, etc., on the gun-deck between bulkheads 74 and 78.

Sets Nos. 9 and 10.—To supply fresh air to engine-rooms.

Sets Nos. 11 and 12.—To supply fresh air to junior and ward-room officers' quarters, general workshop, etc., on berth deck between bulkheads 72 and 94.

Set No. 13.—To supply fresh air to sick bay, operating-room, dispensary, band-room, commissary store-room and passages on the berth-deck forward of bulkhead 24; also to torpedo-room and store-rooms below the berth-deck forward of bulkhead 24.

Sets Nos. 14 and 15.—To supply fresh air to magazines and store-rooms below the berth-deck and between bulkheads 24 and 35.

Sets Nos. 16 and 17.—To supply fresh air to compartments on the berth-deck between bulkheads 24 and 40½; also to communication and distribution-rooms in forward dynamo-room.

Sets Nos. 18 and 19.—To supply fresh air to forward dynamo-room.

Sets Nos. 20 and 21.—To supply fresh air to after dynamo-room.

Sets Nos. 22 and 23.—To supply fresh air to magazines and store-rooms below the berth-deck between bulkheads 83 and 94.

Set No. 24.—To supply fresh air to quarters and other compartments on the berth and protective-decks aft of bulkhead 94; also to supply air to bath-rooms on the gun-deck aft of bulkhead 94.

Set No. 25.—To exhaust from steering compartments on upper platform-deck.

Sets Nos. 26, 27, 28, and 29.—To supply fresh air to communication passages between bulkheads 35 and 83.

Set No. 30.—To exhaust from after dynamo-room.

VENTILATION TABLE.

Set No.	Type of Fan.	Motor. Classification.	Motor. Kind.	Panel Type U. S. Size.	Capacity of Fan, cubic ft.*	Fan. Kind.	Location. Deck.	Location. Frame.	Location. Side.
1	45 S. P.......	M. P.....4....3.75 H. P..... 730/ 980... 125 V...	Enclosed	No. 1.	3026/ 3895	Exhaust.	Gun..........	8-9	Amd.
2	4 Mon'g.. ..	B. P.....2.....1.1 H. P.....1080/1450....125 V...	Open.....	No. 1.	876/ 1209	"	Berth...............	36-37	Port.
3	4 Mon'g.....	B. P.....2.....1.1 H. P.... 1080/1450 ...125 V...	"	No. 1.	877/ 1181	"	"	36-37	Stbd.
4	6 Mon'g.....	B. P.....2... .2.7 H. P..... 820/1190....125 V...	Enclosed	No. 1.	1942/ 2610	"	Gun..	42-43	"
5	6 Mon'g.....	B. P.....2.....2.7 H. P..... 820/1190....125 V...	"	No. 1.	1941/ 2594	"	"	58-59	"
6	30 S. P........	B. P.....2 ...1.65 H. P.....1115/1485 ...125 V...	"	No. 1.	1192/ 1611	"	"	65-66	Port.
7	2 Mon'g.....	B. P.....2 ... .75 H. P.....1750/2125....125 V...	"	No. 1.	486/ 605	"	"	65-66	Stbd.
8	2 Mon'g.....	B. P.....2. .. .75 H. P.....1750/2125....125 V...	"	No. 1.	485/ 618	"	"	65-66	Port.
9	80 S. P..	M. P.....4 .....12 H. P..... 430/ 525 ...125 V...	"	No. 3.	10609/18245	Supply.	"	75-76	Stbd.
10	80 S. P........	M. P.....4......12 H. P..... 430/ 525....125 V...	"	No. 3.	10662/13330	"	"	75-76	Port.
11	55 S. P......	M. P.... 4.....5.8 H. P..... 615/ 820 ...125 V...	Open.....	No. 1.	4648/ 5699	"	"	82-83	Stbd.
12	55 S. P........	M. P.....4.....5.8 H. P..... 615/ 820....125 V...	"	No. 1.	4231/ 5789	"	"	82-83	Port.
13	60 S. P........	M. P.... 4.....7.4 H. P..... 605/ 730....125 V...	"	No. 2.	6401/ 7902	"	Berth	12-13	Stbd.
14	50 S. P..	M. P.....4.....4.6 H. P..... 670/ 930....125 V...	"	No. 1.	3109/ 4605	"	"	34-35	Port.

15	50 S. P.	M. P.....4.....4.6 H. P..... 670/ 980....125 V...	"	No. 1.	3112/ 4568	"	"	34-35	Stbd
16	45 S. P.	M. P.....4....3.75 H. P..... 730/ 980....125 V...	"	No. 1.	3086/ 3302	"	"	36-37	Port.
17	45 S. P.	M. P.....4....3.75 H. P..... 730/ 980....125 V...	"	No. 1.	2584/ 3877	"	"	36-37	Stbd.
18	60 S. P.	M. P.....4.....6.3 H. P..... 605/ 730.. .125 V...	"	No. 2.	5341/ 6539	"	"	37-38	Port.
19	60 S. P.	M. P.....4 ....6.3 H. P..... 605/ 730....125 V...	"	No. 2.	5341/ 6608	"	"	37-38	Stbd.
20	60 S. P.	M. P.....4.....6.3 H. P..... 605/ 730....125 V...	" ...	No. 2.	5392/ 6549	"	"	70-71	Port.
21	60 S. P.	M. P.....4.....6.3 H. P. ... 605/ 730....125 V...	"	No. 2.	5357/ 6539	"	"	70-71	Stbd.
22	45 S. P.	M. P.. . 4....3.75 H. P..... 730/ 980....125 V...	"	No. 1.	2812/ 3883	"	"	82-83	Port.
23	45 S. P.	M. P.....4....3.75 H. P..... 730/ 980....125 V...	"	No. 1.	2644/ 3798	"	"	82-83	Stbd.
24	40 S. P.	B. P.....2... .2.6 H. P..... 800/1080....125 V...	"	No. 2.	2259/ 2830	"	"	110-111	Port.
25	40 S. P.	B. P.....2... .2.6 H. P..... 800/1080....125 V...	"	No. 2.	2105/ 6385	Exhaust.	"	110-111	Stbd.
26	4 Mon'g	B. P.....2.....1.1 H. P.....1080/1450 ...125 V...	Enclosed	No. 1.	878/ 1185	Supply.	Upper platform.....	45-46	Port.
27	4 Mon'g	B. P.....2.....1.1 H. P.....1080/1450....125 V...	"	No. 1.	877/ 1177	"	" "	45-46	Stbd.
28	4 Mon'g	B. P.....2.....1.1 H. P.....1080/1450....125 V...	"	No. 1.	893/ 1185	"	" "	67.5-68	Port.
29	4 Mon'g	B. P. ...2.....1.1 H. P.....1080/1450 ...125 V...	"	No. 1.	883/ 1211	"	" "	67.5-68	Stbd.
30	35 S. P.	B. P.....2.....2.2 H. P..... 980/1225....125 V...	Open.....	No. 1.	1718/ 2110	Exhaust.	Dynamo platform...	71-72	Port.
31	4 Mon'g	B. P.....2.....1.1 H. P.....1080/1450....125 V...	"	No. 1.	877/ 1185	Supply.	Upper platform.....	94-95	Stbd.
32	4 Mon'g	B. P.....2 ....1.1 H. P.....1080/1450 ...125 V...	" ...	No. 1.	877/ 1177	"	" "	94-95	Port.
33	45 S. P.	M. P.....4... 3.75 H. P..... 730/ 980....125 V...	"	No. 1.	2816/ 3823	"	" "	99	Port.

* From manufacturers' tests.

Sets Nos. 31 and 32.—To supply fresh air to store-rooms on upper and lower platforms; to torpedo-room, and in hold between bulkheads 94 and 98.

Set No. 33.—To supply fresh air to steering compartments and store-rooms on upper platform aft of bulkhead 98; also to the hold between bulkheads 98 and 101.

There are several blower assemblages installed; the Monogram (B. F. Sturtevant & Co.) fan with General Electric Company's motor; Monogram fan with Sturtevant motor; Monogram fan with Holtzer-Cabot motor; the Steel Plate fan (Sturtevant) with

FIG. 170.—50-inch blower assembly.

Holtzer-Cabot motor; and General Electric Company's fan and motor. All have many details in common and of which the 50-inch combination of Steel Plate fan and General Electric Company's motor, as shown in Fig. 170 may be taken as a familiar example.

The steel-plate fans are built up of steel plate and angle bar. The motor is supported by a steel-plate base attached to the fan casing, the motor being insulated from the foundation and fan shell by ⅜-inch fiber saturated in paraffin. The fan wheels are of steel with brass hubs keyed on the shaft, a set screw being provided in the hub.

The motor shown is of the shunt, open-frame, 6-pole, circular-

frame type, but reçent types have an enclosed motor, but with an opening at the communtator end for access to the brushes.

The Controller.—The type of starting rheostat used is similar in appearance to that shown in Fig. 157, but as the motors of more than 1 horsepower are to have a varying speed of 20 per cent, a separate lever is provided for changing the resistance in the field circuit. This is shown in the connection diagram of Fig. 171. For varying sizes of motors the No. 1, 2, or 3 size of rheostat panel is provided in accordance with the output of the motor.

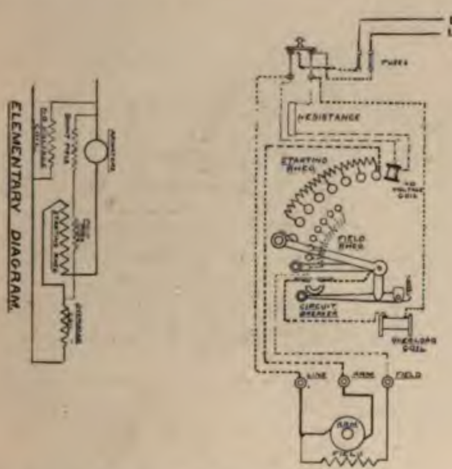


FIG. 171.—Connection diagram of controlling panel for ventilating blowers.

The Monogram type of fan with partially enclosed motor is shown in Fig. 172. This type is more commonly used for exhauster fans or those requiring small power, though there are exceptions in each case.

The type of motor shown is a common commercial type and is frequently made dust proof by covering the openings of the casing with removable doors of brass gauze.

The Portable Fan (¼ Horsepower).

There are several types of this apparatus, often called the portable ventilating set, extant, but a common variety is that shown in Fig. 173; the casing on the commutator end has been removed to show the interior of the motor compartment.

This apparatus is primarily intended for drying out double bottoms, and is supplied with two 25-foot lengths of 4-inch canvas hose which are to be attached to the nozzle. There are six curved fan blades attached by spider legs to a sleeve which is mounted directly on the motor armature shaft. But one long bearing is used, situated between the armature and the sleeve. The motor is on the right-hand side when facing the outlet.

The rated horsepower of the motor is 1/4 horsepower, giving a speed of 2200 r. p. m. for a rated input of 3 1/2 amperes at 80

FIG. 172.—Monogram fan.

volts; a variation of speed of 10 per cent above or below 2200 r. p. m. may occur for the rated input.

The minimum cubic feet of air delivered per minute, free exhaust, is 500. The minimum velocity of air in feet per minute, free exhaust, is 4000 if tested by aneometer, or 3500 if tested by water gauge. The latter method is preferable.

The motor is 4-pole, and is series-wound since the load is constant. The field cores are cast in one with the circular motor frame, the coils being slipped on and held by the pole pieces.

Only two brushes, of the pig-tail type, 3/4 by 3/8 by 2 inches are used, and are set 90 degrees apart, the armature being cross-connected. No rocker arm is required as the machine runs fully

loaded and no shifting of brushes is necessary after the original adjustment is made.

The journal is lubricated by a sight feed oil cup, which has sufficient capacity for an 8-hour run. After passing over the journal the oil runs down into a receptacle at the bottom and is drawn off through a drip cock.

The motor has no starting rheostat or other method of control.

Bracket and Pedestal Fans.

These fans are of 1/6 horsepower and 1/12 horsepower. But few pedestal fans are now used, the adjustable bracket having taken their place on board ship.

FIG. 173.—1/4 H. P. portable ventilating set.

FIG. 174.—Bracket fan, 1/12 H. P.

The ordinary type of bracket fan, 1/12 horsepower, is shown in Fig. 174. The 1/6 horsepower only differs in being larger and having a 16-inch fan instead of the 12-inch for the 1/12 horsepower size.

The general arrangement of the fan construction is shown in the cross-section of a pedestal fan in Fig. 175.

The armature is of the drum type with 12 circular slots in the periphery for the 1/12 horsepower. A narrow groove is cut into each slot, making an opening through which the wire is inserted in winding. The slot being practically closed renders bands unnecessary for resisting the centrifugal force on the conductors, and also reduces the reluctance of the air gap and the magnetizing force required for it to a very low amount, resulting in a

very efficient and economical construction for a machine of this small size.

The special feature of the design is the use and disposition of the single field coil which produces the magnetic field. The construction omitting guard, for the pedestal type, is shown where the armature is shown in full side view and the bearings, field magnet, and spool are in half section.

The poles each encircle about 130 degrees of the periphery of the armature, and are joined to the field magnet at opposite ends

FIG. 175.—Cross-section of pedestal fan.

rather than equally around the center as in the conventional construction. This admits of enclosing the circular field coil between the two halves of the field magnet in the portion shown. The magnetic circuit is but slightly lengthened in the poles in this construction but is compensated for by other desirable features.

Different constructions of the rheostat and regulating switch have been used, the one represented being a metal base on which is mounted a slate block containing the contact buttons and binding posts, and from which the circuits and taps (three) from the resistance wire, which is insulated by enamel from the vertical tube, are led.

The two brushes are of carbon, cylindrical in form, 1¼ inch long by 5/16-inch diameter, for both the 1/12 horsepower size and the ⅙ horsepower size. The oil cups contain a cylinder of felt which lifts the oil to the spindle bearings by capillary attraction. A spring keeps the felt in contact with the shaft and compensates for wear.

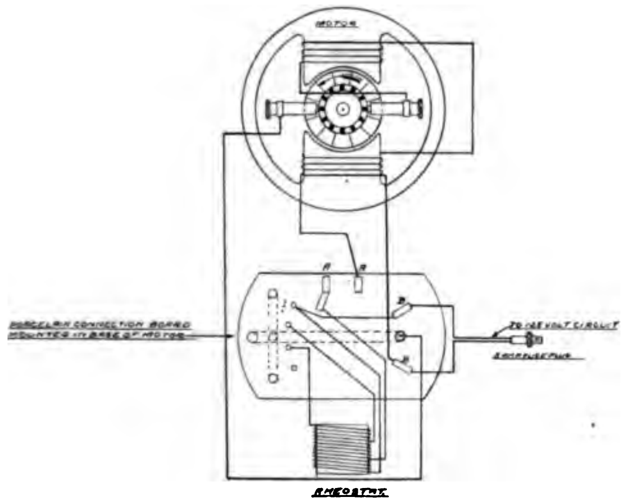


FIG. 176.—Connection diagram of bracket fan.

The latest design for fans of ⅙ and 1/12 horsepower are arranged to be converted into either a pedestal or bracket fan at will; they are further designed to be used on either a 125-volt or 80-volt circuit by merely changing the connections as shown in Fig. 176, for the 125-volt circuit connections are made to *BB*, as shown; if to be used on an 80-volt circuit connections are made to *AA*.

CHAPTER IX.

MISCELLANEOUS MOTOR APPLICATIONS.

Motors for Operating Power Doors and Hatches.

The electrical drive for the long-arm system installed in the *Florida* contemplates only the operation of the air compressor; the doors are operated by pneumatic pressure acting on one or the other side of a piston which slides in a barrel attached to the door, the operating pressure being about 500 pounds per square inch.

On board the *Connecticut* each power door and hatch is operated by its separate motor; the system comprises two emergency stations located on the forward bridge, and 23 vertical and 19 horizontal sliding doors, as well as five protective-deck hatches. Two emergency stations are utilized because the capacity of one station is insufficient for the operation of the total number installed.

Power Doors.

The two types of *door,* horizontal and vertical, are shown in Fig. 177, *A* and *B*. Each door is supplied with two removable hand wheels that the device may be operated by hand in case of failure of the electrical supply to the motor; the hand wheels are stowed in the immediate vicinity of the door. The wedges are drop-forged of bronze; each wedge works on a hard brass roller mounted on a bronze pin, this arrangement preventing any refusal in closing due to foreign objects or coal about the wedges. It also operates to prevent an unreasonable escape of water for which specifications require not more than 10 gallons per minute under a head of 35 feet, and not more than 2½ gallons per minute under a head of 20 feet. The door plate is driven from the motor or hand wheel by a system of gearing, and in each type a worm is introduced which will cause the thrust on the door plate to bear a direct ratio to the end thrust exerted by the worm. The end thrust is resisted by a helical spring, which is subjected to an initial compression sufficient to effect water-tight closure with-

out further load on the spring. If the thrust on the door plate in closing or opening exceeds this initial compression the spring yields and operates the limit switch in the controller, the limit switch acting to cut off the electrical supply to the motor. In the case of the vertical sliding door, the worm acts directly on the worm rack on the door plate; the end of the worm is cut off squarely to sweep out any coal lodging in the rack. In the case of the horizontal sliding door, the driving is accomplished by two

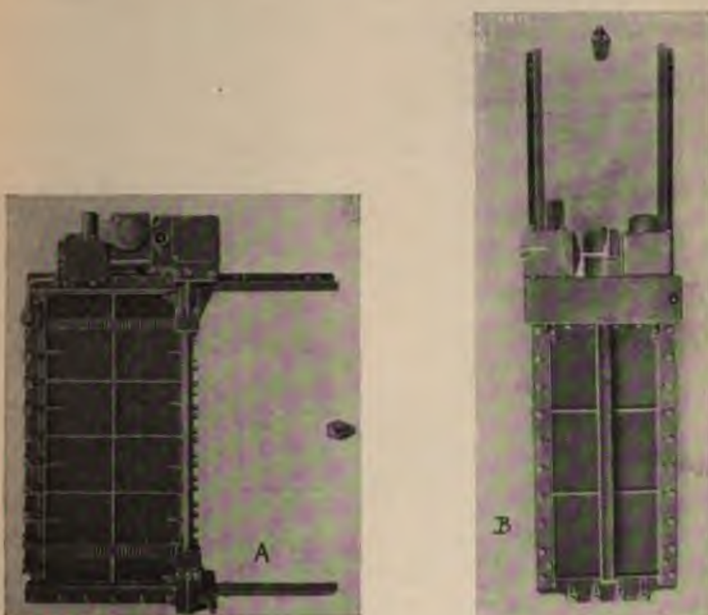


FIG. 177.—Horizontal and vertical water-tight doors (closed).

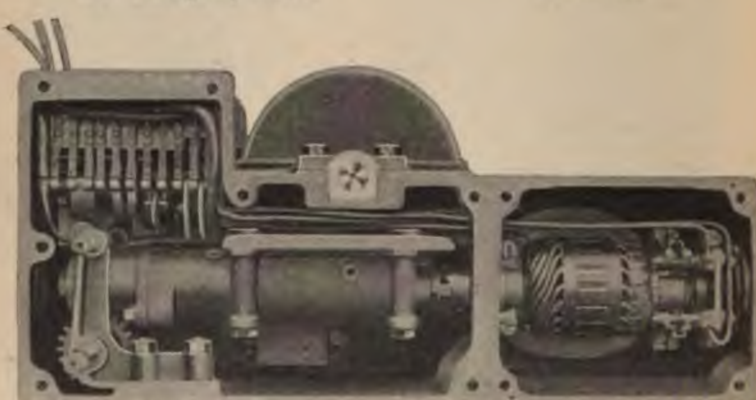
racks meshing with spur pinions. The rack teeth being vertical free themselves of foreign matter which might lodge.

The working parts of the *emergency station* are contained in a water-tight brass case mounted on the wall of the pilot-house or at any other convenient place running to the bridge. The device is shown at *A*, Fig. 178. The apparatus has three parts: first, *the mechanism for controlling the circuits running to each door or hatch;* second, *the lamps to indicate the closure of each door or hatch.* A sketch of the connections for these functions is

shown in Fig. 179. Third, *the fuse box.* The hand wheel is grasped at the hub and pulled away from the cover until the lug on the hand wheel clears the notch on the cover. The wheel is then turned to the right—with the sun—until the lug passes over

A.—Emergency station.

B.—Motor.



C.—Power box.

FIG. 178.

the notch projection. The hand wheel is then let go and the device, by releasing a large spring and controlled by an escapement will close all solenoid circuits at about 3 seconds interval. The gearing does not start all circuits at the same instant—as the

current demanded in such a case would be excessive—and seldom more than four motors are in operation at the same time. The entire closure of 25 doors and hatch gear operated by one station should be accomplished in about 75 seconds. As each door is locked, a circuit running to the emergency station box is closed and lights a small incandescent lamp over each lamp; forming part of the case is a small translucent disc bearing the number of the corresponding door; by pressing a button the operator can assure himself of the closure of all doors; if any lamp fails to glow, that door is not closed. Though each door and hatch can

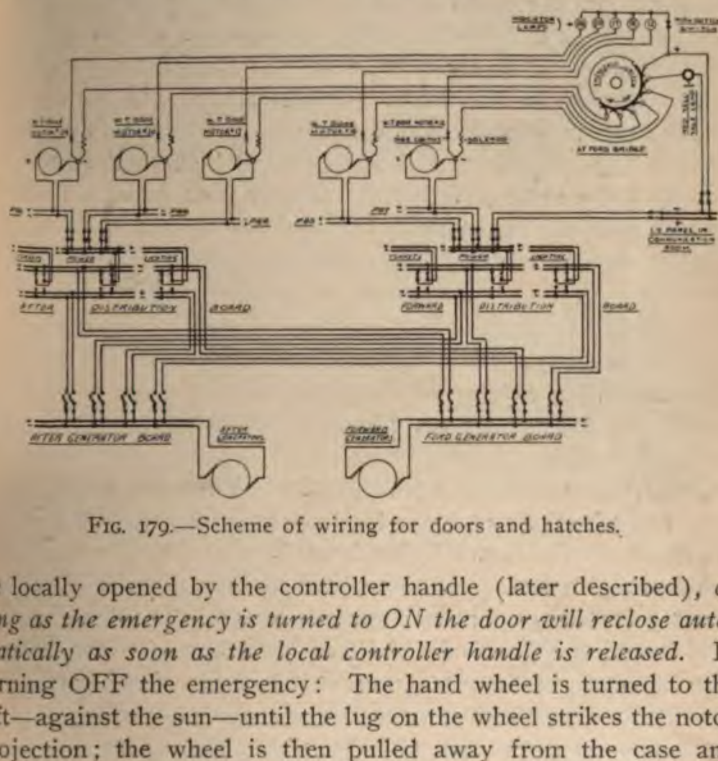


FIG. 179.—Scheme of wiring for doors and hatches.

be locally opened by the controller handle (later described), *as long as the emergency is turned to ON the door will reclose automatically as soon as the local controller handle is released.* In turning OFF the emergency: The hand wheel is turned to the left—against the sun—until the lug on the wheel strikes the notch projection; the wheel is then pulled away from the case and turned to the left until the lug is opposite the notch; letting go the wheel will now permit the lug to enter the notch on the case. Before taking off the cover of this device the current for the entire system should be turned off at the switchboard. In order that the operator may be sure that current is on, as soon as the first solenoid circuit is closed the red lamp under the red disc will

glow and will continue to glow until the circuit is broken by the emergency at OFF.

The motor (Fig. 178, *B*) is direct-current, reversible, compound-wound, iron-clad, bi-polar. It is entirely enclosed within a water-tight case and capable of a normal output of 1 horse-power at 125 volts, with a speed of 1200 r. p. m.; it is also capable of carrying 50 per cent overload for 5 minutes, and four times its rated input for 10 seconds.

The controller and motor, enclosed in a **power box** are shown in Fig. 178, *C*. In the operation of the controller, by means of the handle on the controller and the handle located on the opposite side of the bulkhead or deck, the handle is normally held in mid-position by a spring, from which position closure or opening of the door can be effected by moving the handle in one direction or the other; when released the handle will return to mid-position; in the case of vertical and horizontal doors the handle is moved in the same direction as the door is to move. To avoid complication, the method is not applied for hatches.

The controller device has three essential parts: First, *The switch for local operation of the door or hatch by means of the local handles.* Second, *The emergency switch, for closing the door or hatch, operated from the emergency station.* Third, *The limit switch for cutting off the motor current when the load on the operating parts exceeds a predetermined limit, e. g.*, the door or hatch reaching the end of its travel in opening or closing, or encountering an unyielding obstruction. Referring to Figs. 180, 181, and 185, the switch for local operation consists of five segments, *A*, *B*, *C*, *D*, and *E*, insulated from and rigidly secured to the drum shaft on the end toward the operating handle *F*. These five segments engage seven fingers as shown. The drum shaft *G* is driven from the handle shaft *H* by means of miter gears *J*. The segments of the emergency switch *K* also form part of the circuits for operating the controller by the handle; this emergency switch *K*, shown in Figs. 180, 181, 182, and 185, is assembled on the drum shaft next to the switch for local operation and rocks freely on that shaft. It is held in normal position (Fig. 182) by a spring *L*, and is moved down, so that its two insulated contacts engage the fingers, by the rising of the solenoid plunger *M* when attraction results from a current in the solenoid winding. The same movement of the emergency switch occurs by the switch *K*

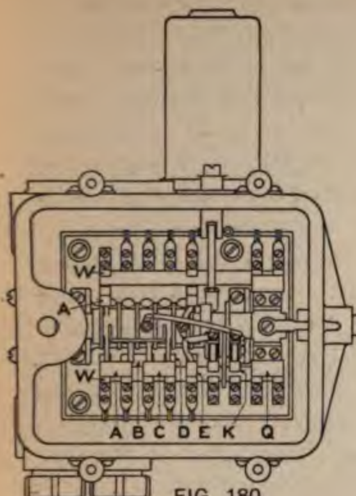


FIG. 180

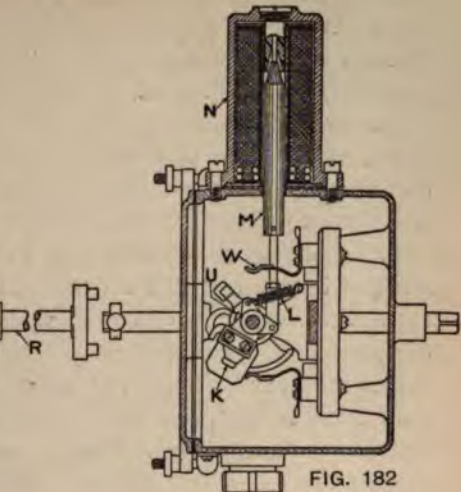


FIG. 182

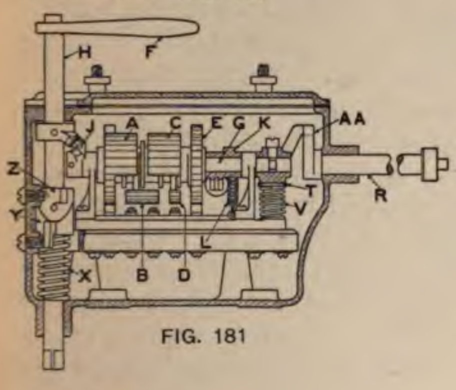


FIG. 181

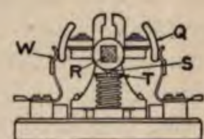
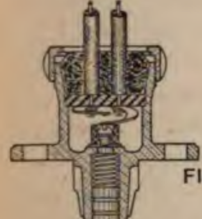


FIG. 184 LIMIT SWITCH
SWITCH IN CENTRAL POSITION



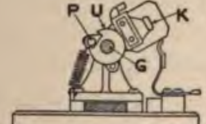


FIG. 183 LIMIT SWITCH
SWITCH THROWN

FIG. 185 EMERGENCY SWITCH

FIG. 186

engaging, through a pin *P*, the side of the slot on the collar *U* of the drum shaft *G;* hence, in closing the door, either by hand or through the emergency station, the circuit is completed through the emergency switch *K*. It will be noted that the operation of the emergency switch by the solenoid does not interfere with operating the door or hatch by the local controller handles, and that as soon as the local handle is released the emergency is again brought into action to close the door or hatch.

The limit switch *Q*, shown in Figs. 180, 182, and 184, is assembled on the end of the drum shaft *G* and rocks freely about the shaft. Its insulated contacts engage four fingers, as shown; this device is operated by the helical spring before mentioned. When the door or hatch has either opened or closed with sufficient force to compress the helical cut-out spring the spindle *R*, entering the controller, rotates through 30 degrees in one direction or the other, moving the limit switch with it. If, for instance, the motion of the limit switch opened the contact between the upper insulated segment and its two fingers the circuit to the motor is broken and the motor will stop. The connection between the lower insulated contact and its two fingers will not, however, be broken by this action, and the circuit, *for operating the motor to open the door,* being closed by this contact will not be bròken; if the limit switch had been moved in the opposite direction to that just explained, the circuit through the upper contact would remain closed, tending to close the door or hatch. The particular way in which the limit switch moves on closing the door or hatch depends upon the mechanical connection between the helical cut-out spring and the limit switch; this is somewhat different in the various devices, in some the upper contacts open when closing the door or hatch, in others the lower contacts open for the same purpose.

The **contact box** is to provide means of closing the circuit to the indicator lamp at the emergency station when the door or hatch has reached its closed position. The standard form of the box is shown in Fig. 186. It is a spring switch operated by a plunger which engages a wedge carried by the door plate in power doors; in the case of hatch gears the plunger is acted on by a lug carried by a collar on the crank shaft of the hatch lift. In case the indicator lamp fails to glow when the door or hatch is closed the difficulty can frequently be located in this box.

Power Hatches.

The electrical features for the hatch are the same as for the door but the mechanical details are distinct; an installation for the link-connected lever is shown in Fig. 187.

Referring to Figs. 188 and 189 the hatch plate is raised and lowered by bent levers *A*, which are secured to the fulcrum shaft *B*, and rock with it. This fulcrum shaft is in turn driven from the hatch lift crank by either a link connection, shown in Figs.

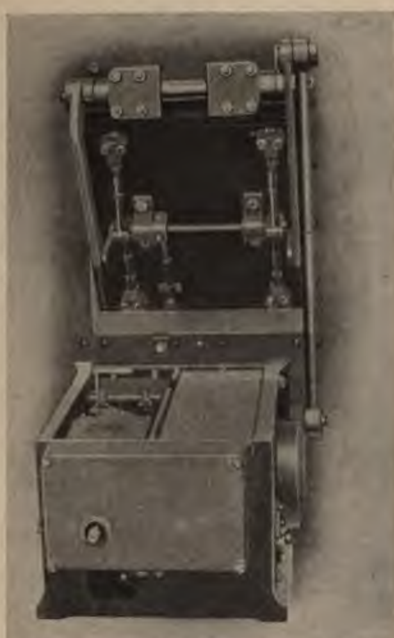


FIG. 187.—Hatch gear. View looking up beneath the protective deck showing hatch plate partly open.

188 to 192, or by a slot and roller. The connection between the bent lever and the hatch plate is through links *C*, connected to the cranks *D* on the locking shaft *E*. The hatch plate in locked position is shown in Figs. 188, 189, and 190. When the bent levers move up the shaft *E* is rotated until *D* touches *F*; no further rotation of *E* then occurs and *F* is in the position of Fig 191; this slight rotation withdraws the roller bars *G* and unlocks the hatch. In closing the action is reversed. The object of the

FIG. 192

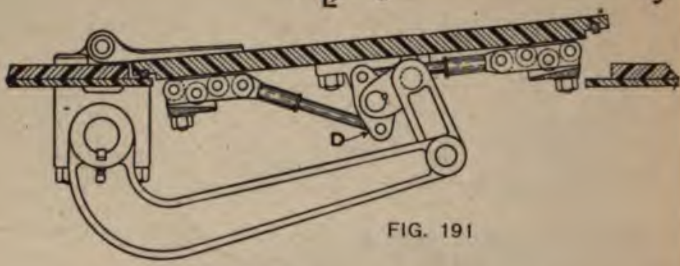


FIG. 191

FIG. 190

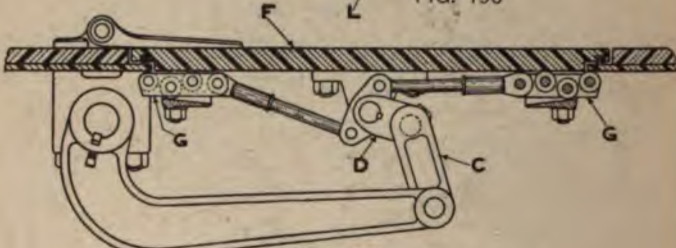


FIG. 189

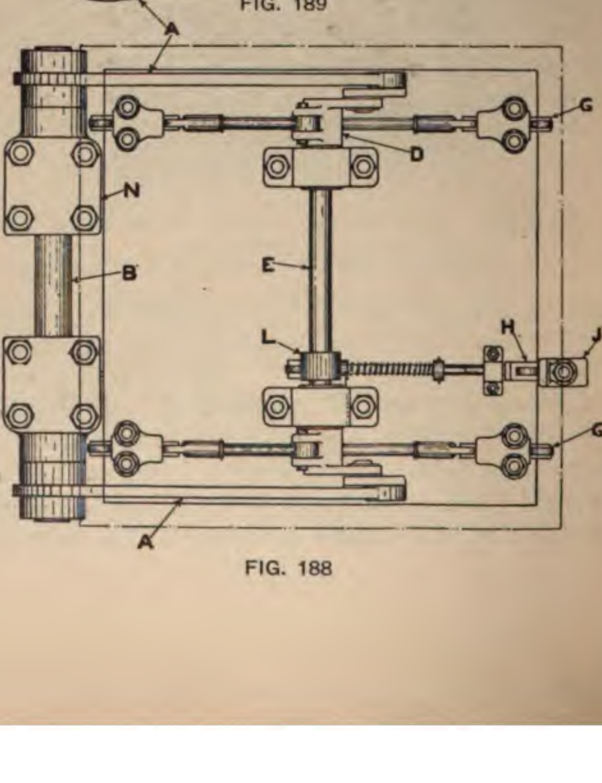


FIG. 188

roller *H*, which engages the stop *J* is to prevent *E* from rotating and this is accomplished by moving *K* away under the action of its spring. The shaft *B* is operated by the rod shown at the side in Fig. 187, which, acting from the worm shaft to a bell-crank-shaped end of the bent lever *A*, if for the slot and roller type (Fig. 187), or the crank of the worm shaft moves in a guide attached to the bent lever if of the link type (Figs. 188 and 189). The limit switch spring is practically the same as for doors.

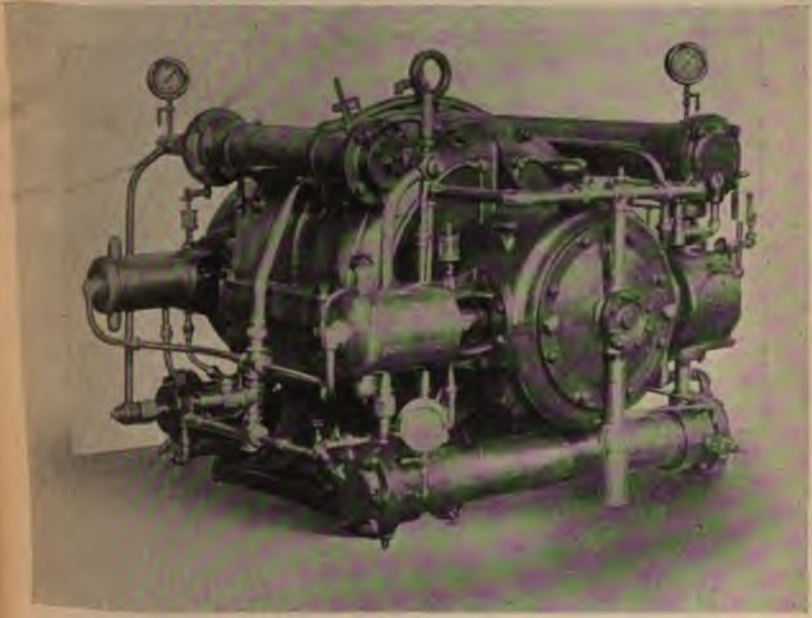


FIG. 193.—Torpedo air compressor assembly.

Torpedo Air Compressor Motors.

The Platt Iron Works assemblage of this large apparatus is shown in Fig. 193. The dimensions in inches are 87 by 61 by 59 high, with a weight of 9000 pounds. The compressor delivers 30 cubic feet minimum of air per hour at 2500 pounds pressure per square inch, with volumetric efficiency of at least 90 per cent and not less than 80 per cent efficiency. A by-pass is fitted to start against full 2500-pound pressure. Pressure gauges for second and intermediate stages of compression are provided; also, sight-feed lubricators on the air cylinder of each stage and separators

on the cooling coils of the first inter-cooler and the after-coo
A self-contained pump maintains the circulation but can be
out for gravity circulation under a head of 10 feet. The wa
cooling system is provided with a safety valve to blow off at
pounds pressure. The motor is 6-pole, shunt-wound, and
velops 80 horsepower, at 125 volts supply, and is capable of
per cent overload for one-half an hour and a momentary overl
of 50 per cent.

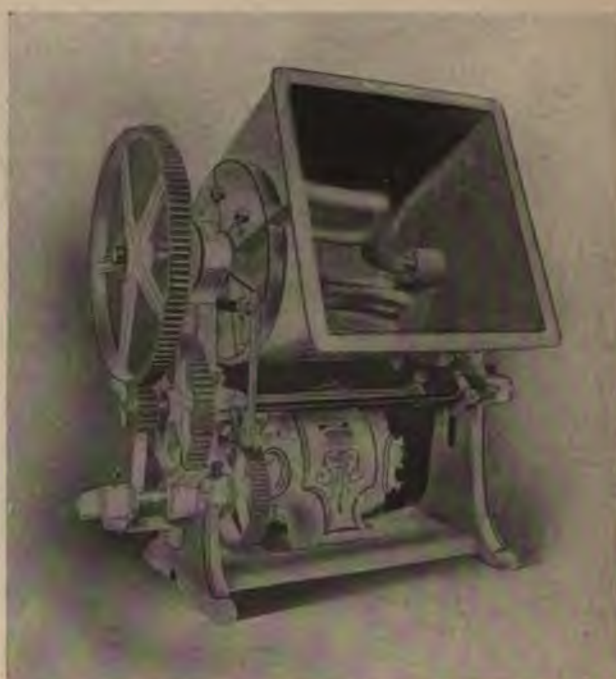


FIG. 194.—Dough mixer assembly.

The starting panel is similar to that shown in Fig. 157, no c
trol of speed being required.

Dough Mixer Motor.

The Day apparatus is shown in Fig. 194. The capacity
one barrel of flour.

The motor is of the 4-pole, shunt type and develops, at 1
volts, 3 horsepower if open, and $2\frac{1}{2}$ horsepower if enclosed.

operates through a train of gears a pair of specially-shaped
or beaters, which knead the dough by their revolution.
is a separate shaft through which the dough box can be
d on a trunnion axis to facilitate removal of the dough, this
being controlled by a hand lever. The controlling panel
er of the type shown in Fig. 157, or is a slate block at whose
e the line connections through enclosed fuses and a double-

Fig. 195.—Dish washer assembly.

witch; at the bottom is mounted a starting rheostat simi-
that shown in Fig. 136, and with the same general
tions.

Dishwasher Motor.

Insinger apparatus is shown in Fig. 195. The dishes and
to be washed are placed in the basket shown and lowered

into the water bath containing water, soap powder, or soapine, and lye, but not sufficient alkali to form suds. Solid matter is first wiped off the mess gear with bread. There are two compartments called *the washer* and *the rinser*. In the *washer* compartment the temperature of the water is kept to that which can be borne by the hand; two three-bladed propellers agitate the water in this compartment, the alkali removing the grease, which last can be drawn off by the overflow. The water in the *rinser* compartment is kept at the boiling point and holds clean pure water; the basket is merely dipped two or three times in this compartment. Heating the water is done by steam connections.

FIG. 196.—Parts of Potato Peeler.

The motor is of ¾ to 1 horsepower, at 125 volts, with a speed of drive of the machine of 310 r. p. m., but must not be less than 300 r. p. m. It drives the propeller shafts through sprockets and gears. The starting rheostat is a Leonard panel form of the type shown in Fig. 136, in which the circuit connections are placed at the top of the panel through enclosed fuses.

Potato-Peeler Motors.

The potato-peeling machine is shown dis-assembled in Fig. 196. The fluted, rotating base of the hopper is revolved by gears on a shaft whose pulley is belt connected to the pulley on the motor shaft, the motor being secured to the deck overhead. The barrel mounts over the rotating parts with its door opposite the trough

shown; the hopper is closed by an open-work cover, whose office is to prevent the potatoes from pushing over the top of the barrel. A steady stream of water flows in at the top of the hopper and out at the base. The top of the fluted rotating base and the inside surface of the hopper have a cut surface similar to that of a file, and, as the potatoes are raised and mixed by the fluted rotating base, they are forced against the side of the hopper, the peel being rubbed off rather than cut and carried away by the water supply. The motor is of the partly enclosed type and develops 1 horse-power at a speed of 1425 r. p. m. It is mounted on a block which is secured to the deck above, a small starting rheostat of panel construction being used in starting. In the last type of rheostat

FIG. 197.—Meat chopper assembly.

a wheel lever is introduced for changing the intensity of the motor field and hence the speed. A no-voltage release is provided; the enclosed fuses are relied on for overload.

Meat-Chopper Motor.

This combination is shown in Fig. 197, and is a direct motor connection to the familiar type of sausage-grinder.

The motor is bi-polar, shunt-wound, developing ¾ to 1 horse-power. A simple starting rheostat is provided but a slow and fast speed are contemplated by a knife switch which introduces a resistance in series with the field, and hence higher speed, when the switch is open, and slows the motor by short-circuiting this resistance when the switch is closed, its normal position.

Pump Motors.

The pump apparatus on electrical drive are fresh-water pumps —usually two— and sanitary, or flushing pumps—also two as a rule.

Fresh-Water Pumps.—Both are similar in design and interchangeable. The pump is of the reciprocating type, being three 4 by 4-inch cylinders which are driven by eccentrics on the pump

FIG. 198.—Type C. R. controlling panel.

shaft. The shaft is fitted with a large fly-wheel. The drive from the motor shaft is effected through a pinion having 18 teeth and a larger gear having 180 teeth; the motor speed is 1000 r. p. m., and that of the pump 100, delivering 65¼ gallons per minute at full motor load.

The motor is shunt-wound, bi-polar, and develops 2 horse-power.

The controlling panel is a type designed for starting motors of less than 3 horsepower, and combining a blow-out coil; it is shown in Fig. 198. The connections are shown in Fig. 199.

Flushing Pumps.—The two pumps are identical and interchangeable. They are of the horizontal, centrifugal type, and direct connected to the motor drive. They deliver 150 gallons per minute at the motor full-load speed at 35-foot head.

The motor is 3-horsepower, 4-pole, shunt-wound, having a speed of 1080 r. p. m.; and is of the partly enclosed type of construction. A controlling panel similar to Fig. 157 is used for starting.

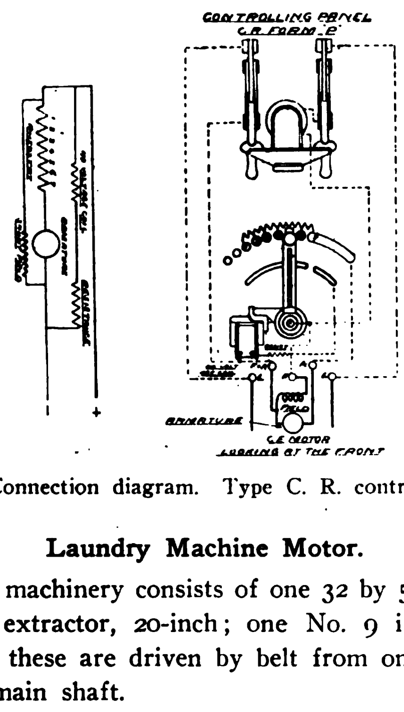


FIG. 199.—Connection diagram. Type C. R. controlling panel.

Laundry Machine Motor.

The laundry machinery consists of one 32 by 54-inch washing machine; one extractor, 20-inch; one No. 9 ironer, and one mangle; all of these are driven by belt from one counter-shaft belted to the main shaft.

The motor is 8-horsepower, 4-pole, shunt-wound, and has a speed of 800 r.. p. m. It is of the partly enclosed, dust-proof type and secured to the deck; the motor drives the main shaft by belt and pulley.

The controlling device is similar to that used for chain ammunition hoists (Fig. 157), but has no separate field switch.

Motors for Power Tools.

The following are the kinds and types in latest battleships:

Gap Lathe, 28-Inch by 48-Inch.

The Harrington type of lathe is driven by gearing, variable speed being afforded by field control.

The motor is 4-pole, shunt-wound, and develops 7½ horse-power; the rated speed is from 740 to 1675 r. p. m.

An especial type of controller is used somewhat similar in construction to that shown in Fig. 203, except that the controller is reversible, and the contact fingers are all in one plane. The connections are shown in Fig. 200. The controller has one starting notch through resistance in series with the armature; the armature having attained its normal speed higher speeds are accomplished by moving the controller handle over the remaining eight notches for "Forward," or four notches for "Reverse," in accordance with speed desired. A shipper bar extends over the length of the lathe enabling the machinist to handle the controller from any position of the carriage.

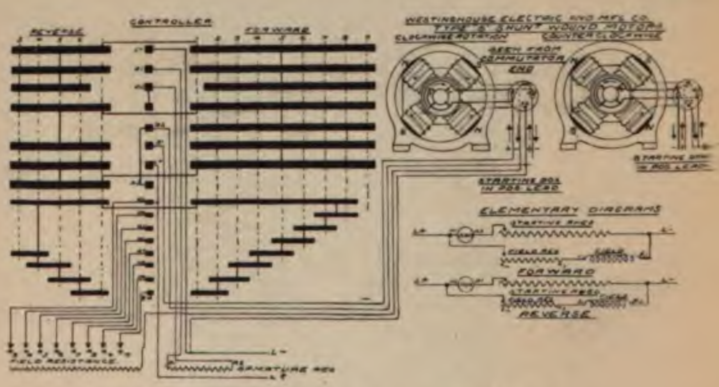


FIG. 200.—Connection diagram 28-inch lathe.

16-Inch Shaper.

This tool is driven by the motor through gearing.

The motor is 4-pole, shunt-wound, and develops 5 horsepower, at a speed of 400 to 1200 r. p. m.

The controlling panel whose connections are shown in Fig. 201 is of the Cutter-Hammer manufacture, type B. Starter

arrangement is made in the connections for variation of speed by field control.

Universal Milling Machine.

The general arrangement for motor drive is the same as for the shaper, except that the drive is by belt.

The motor is 4-pole and develops 2 horsepower, at a speed of 800 to 16,000 r. p. m.

The controlling panel is the same in general details as that used with the shaper motor.

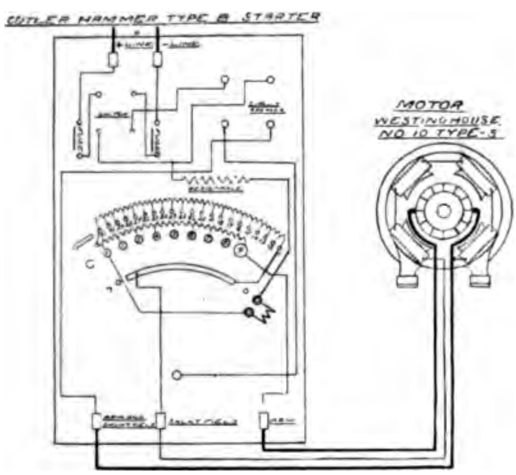


FIG. 201.—Connection diagram 16-inch shaper.

Emery Grinder.

This assembly consists of a 12 by 2-inch emery wheel on each end of the motor shaft, the motor being supported by a column.

The motor is bi-polar, shunt-wound, and developes 2 horsepower, at a speed of 1800 r. p. m., there being a speed variation down to 900 r. p. m.

The method of field regulation to vary the speed is on the Stow system. This system provides a hollow field core for the motor, in which works a plunger, the plunger being driven in or out by gearing. The field effect is, therefore, produced by the change of flux in the armature due to a reduced number of lines of force; that is, the armature flux is practically throttled.

A simple starting rheostat is connected to the motor.

Drill Press, 22½-Inch.

This tool is driven by the motor through gearing.

The motor for the Willey tool develops 1 horsepower, and is 4-pole, shunt-wound.

There is only a simply starting rheostat, the variations in speed of the drill press being effected through belt and cones.

Lathe, 14-Inch.

The drive is effected by gearing to the lathe.

The motor develops 1 horsepower, is 4-pole, shunt-wound, and has a variable speed under field control from 500 to 1500 r. p. m.

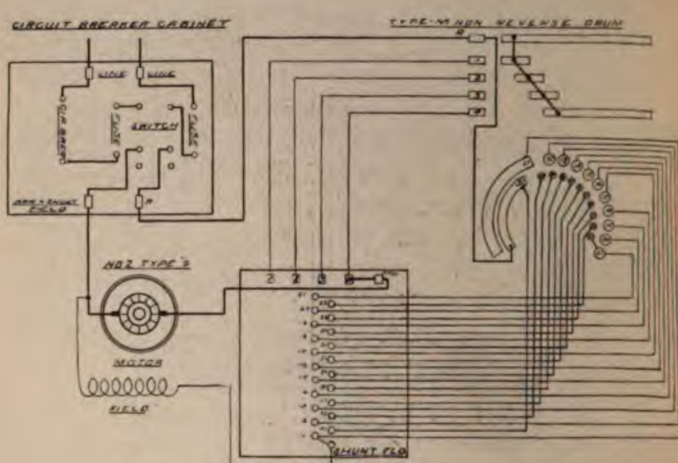


FIG. 202.—Connection diagram, 14-inch lathe.

The connections of the controller are shown in Fig. 202. The non-reverse drum (Fig. 203) is in effect a type of controller for uni-directional rotation of the motor; the lower contact arc regulates the field as, after the armature acceleration is completed, a farther motion of the drum spindle will cut resistance into the field circuit on the several points, thereby gradually accelerating the motor speed, or driving the motor at the desired working speed.

Sensitive Drill Press.—This small tool is driven directly by the motor, which is mounted on top of the drill shaft.

The motor is shunt-wound, bi-polar, developing ¼ horsepower.

The starting rheostat is of the plug-drum type. This type of rheostat is a cylinder mounted on the motor frame and has a contact arc with two steps; the arc short-circuits the resistances in turn.

Propelling Motors.

Propelling Submarine Torpedo Boats.

The following description applies to the installation of the *Plunger:*

Gasolene Engine.—The main motive power is supplied by an "Otto" gas engine of the inverted marine type, built by the Otto

FIG. 203.—Non-reverse drum controller. 14-inch lathe.

Gas Engine Works, having four single-acting cylinders, diameter $11\frac{1}{4}$ inches, stroke 14 inches, in pairs, mounted upon one frame which is bolted to the engine bed. It is of 160 horsepower, at 360 r. p. m., and consumes about .853 pint of gasolene per horsepower hour. It is fed from a gasolene tank of 850 gallons capacity. The engine drives the boat at a speed of about 8 knots per hour at full speed. The engine is intended to drive the vessel while on the surface only; it also drives the main motor as a dynamo to charge the storage battery. Under water, the engine is disconnected from the main shaft of the vessel and the motor is used as the propelling power.

The engine drives the propeller, the motor used as a generator and the air compressor.

Each pair of cylinders has one common jacket cast in one piece with the two cylinders. The cylinders, cylinder heads, and exhaust-valve casings are water-jacketed throughout, each pair of cylinders having one common jacket cast in one piece with the two cylinders. The circulating pump, capacity 40 gallons per minute, is driven by a gearing from the engine. From the exhaust-valve casings, the circulating water is carried through a pipe connection to a water-jacket on the exhaust pipe and so overboard. The pistons are of the trunk type with long-bearing surfaces, running tight, and having four packing rings each. They act as cross-heads, the connecting rods being attached directly to the pistons. The crank shaft is supported by three main bearings, one at each end and one in the middle. The bearings are lined with phosphor bronze. The exhaust valves are located on the top of the cylinder head, the gasolene and air valves on the starboard side of the cylinder head, the air suction being taken from the closed crank pit. All valves are of the poppet type, and are operated by levers actuated by cams on the fore and aft shaft on the starboard side near the top of the cylinders. All valves have spring returns. The cam shaft makes one-half the number of revolutions of the crank shaft, the motion being transmitted from the latter by two pairs of skew gears through a vertical intermediate shaft on the after end of the engine. The oil reservoirs are located on the port side of the engine, one on each pair of cylinders. Each reservoir is provided with compartments for cylinder oil and for oil for bearings, with sight feed and valves for adjusting the flow. The governor is of the centrifugal ball type, and controls the speed of the engine by regulating the charges of fuel admitted.

The igniters are electric, of the make and break type. The plug consists of a cast-brass shell projecting into the explosion chamber, the outer end carrying an oval flange for securing to the cylinder. The axis holes are bored through the plug-carrying rods Nos. 1 and 2. Rod No. 1 has a gas-tight shoulder joint, and is grounded to the plug; it carries on its inner end a contact, platinum-tipped, which works between a platinum ring on the end of rod No. 2, and a stop on the inner face of the sparking plug. The outer end is fitted with a spring return trip operated

ι blade on an eccentric rod connected to the valve shaft of the ine. No. 2 hole contains a stationary rod, tipped on the inner with a platinum ring, where the contact is made and broken. s rod is insulated from the plug by an asbestos washer and a ι bushing, the securing nut on the outside serving as a binding t for the connection from the ignited board. The ground contion is made from the gasolene valve to the igniter board. plicate sparking coils are mounted on the sparking switchrd which are fed by duplicate batteries of four cells each, conted in series so that one battery may be charged while the er is in use, a double-pole, double-throw switch being fitted this purpose. A 60-volt, 16 c. p. lamp for resistance, and a mpere fuse are placed in the circuit between this switch and main switchboard. The discharge of the igniter batteries is trolled by a triple-pole, double-throw switch. The outside es are connected to the positive and negative ends and to the ter of the battery. The middle connections are to the sparking s and to the ground wire on the engine. Between the sparkcoils and the igniters four single-throw switches are inserted, ough which one coil feeds cylinders 1 and 4, while the other ds cylinders 2 and 3.

\ small gasolene hand pump is bolted to frame of the engine ward on the starboard side. This is connected to a small olene reservoir and the necessary valves for mixing air and l attached to the hand-pump cylinder. A charging pipe is led n here to each cylinder with the necessary valve for admitting rges to the cylinder.

he engines are of the "Otto" four-cycle type, the operations ng place as follows:

Suction Stroke.—During the first suction stroke of the piston ı the air and gasolene valves open, a cylinder full of mixture ;asolene and air is drawn into the cylinder.

Compression Stroke.—On the return stroke, all valves are ed, the mixture is compressed, and near the end of the stroke ;nited by means of an electric spark.

. *Expansion Stroke.*—During the following forward stroke, piston is driven by the combustion and expansion of the mix- :.

. *Exhaust Stroke.*—During the return stroke, the products of

combustion are expelled, the exhaust valve being opened at the beginning of the stroke.

The Main Motor.—This is actuated by the gas engine, when running on the surface, as a generator, and by the storage battery, when submerged, as a motor. It is a 4-pole, shunt-wound machine, developing 70 horsepower, at 120 volts and 800 r. p. m. By means of switches in the armature circuit on the main switchboard, it is reversible in direction of rotation. With storage batteries in series, it operates at 60 volts. Working as a dynamo, at 800 r. p. m., it delivers 500 amperes at 60 to 70 volts, to charge the battery; the usual charging current will be lower than this. The machine is designed and tested for 25 per cent overload at 120 volts for a half-hour's run without injury to the insulation.

The storage batteries are of the chloride accumulator type, and made by the Electric Storage Battery Company. They consist of 60 cells and appurtenances, are installed in two water-tight tanks, forming part of the structure of the vessel, lined with wood covered with sheet lead, 6 pounds to the foot (about 0.1 inch), five sheets being used, one each for ends, sides, and bottom, all seams being well lapped and burned bright. The forward tank contains 35 cells, the after tank 25 cells, arranged 5 cells in a row. They are connected in series in one set of 30 cells. The cells are of composite construction, having a steel frame with steel and wood panels, lead-encased and lead-lined, measuring approximately 13½ by 19 by 33½ inches in height, outside, and weighing about 288 pounds. The lead lining weighs 6 pounds per square foot, the bottom 8 pounds, and the covering 4 pounds. An extra flange, ¾-inch wide, extends across the ends of the cells, at the top, to prevent the liquid in the cells from slopping over the edges in diving and rising. A ledge across the ends of the cells, 17½ inches from the top, holds a porcelain filler to prevent the plates from shifting. A sheet of hard rubber is placed in each side of the cell against the lead lining. Each cell is seated on a wooden base, standing on eight (8) glass insulators, the insulators resting on strips of lead to prevent injury to the lead lining of the tank. The cells are wedged in place with wooden battens insulated from the cells by strips of hard rubber.

There are 60 elements consisting of 17 plates each, 9 positive and 8 negative, alternating with 8 positives and 9 negatives, to a cell.

The *positive* plates are of the Manchester type, 27⅜ by 15-5/16 by ⅜-inch thick, weighing approximately 42 pounds. The plates consist of a grid of antimony alloy, cast under pressure, having circular holes ¾ inch in diameter, filled with corrugated soft lead ribbon 5/16 inch in width, rolled in a spiral. The plate is treated by an electro-chemical process, converting it into PbO_2 which, in this condition forms the positive of the battery. The *negative* plates are of the chloride type, and are 27¼ by 15-5/10 by 5/16 inch, weighing approximately 25 pounds. The plates are formed by casting lead antimony alloy in a mould in which are arranged pellets of lead chloride ¾ by ¾ inch, in rows of 16 each. Afterwards, these plates are treated with the positives and reduced to pure lead in a spongy condition. The plates, excepting those leading out at the end, are supported in tandem, one positive and one negative, by copper bars ⅞ by ⅛ inch covered with lead, outside dimensions being 1⅜ by ¼ inch, which rest upon strips of hard rubber on the top of the cells. At each point of contact at the top of the tanks, a hard rubber sleeve is slipped over the bars to insulate them from moisture creeping along the top of the hard rubber insulation. The plates are steadied in place by strips of hard rubber, with T-shaped heads, projecting into the cells the length of the plate, at three places, at each end and in the middle. The plates in the terminal cells, forward and aft, are connected in series by equalizing strips of copper, covered with lead.

The battery terminals lead through porcelain sleeves, corrugated to prevent creeping of acid, extending through flanges on the battery tanks. The terminals are connected to standard insulated wire of 658,000 c. m. by a copper "L," sweated on to the terminal and wire. The wire is led through conduit to the switchboard. The outlets and ends of conduit are enclosed in a wooden box filled with pitch, with a covering board to protect them from mechanical injury.

The cells are charged with the electrolyte, sulphuric acid, and distilled water, with a specific gravity of 1210, until the plates are entirely covered. Distilled water should be added from time to time to replace water lost by evaporation, an exposure of the elements to the air resulting in loss of capacity. As some acid is lost in the spray by ebullition while charging, this also should be replaced from time to time. The weight of electrolyte for each

cell is 220 pounds. Internal resistance of cell when charged, .00015 to .0002 ohm.

[NOTE 25.—The following is an epitome of the instructions entered in *The Record of Electrical Appliances,* furnished vessels using storage batteries:

The simple action of the cell is: When properly discharged, both the positive and negative plates (plugs or active material) is coated with a **black sulphate of lead,** the SO_4 to produce it being derived from the electrolyte, whose density is therefore diminished as the discharge takes place. When charged, the positive plate is surfaced with PbO_2, while the negative plate is surfaced with Pb, in a spongy state, the SO_4 being given back to the electrolyte, whose density is therefore increased as the charging takes place. The difference of potentials between the plates, renders the system analagous to a primary battery. **The positive plate is the positive pole in storage batteries,** and not the negative as in primary batteries.

1. **A battery must always be charged in the right direction.**

This should be self-evident from the difference in construction of the positive and negative grids (plates).

2. **Be careful to give the right amount of charge. Do not undercharge or overcharge to an excessive degree.**

The desirable sulphate of lead which is to be deposited on the positive and negative grids by discharge is the **black sulphate,** which is readily dissolved back into the electrolyte in the process of charging. There is another sulphate produced by undercharging and overcharging known as the **white sulphate,** which is an insulator, which is not soluble in the electrolyte during the process of charging or discharging, and which attaches itself to the grid in the form of an insulating scale producing a condition analagous to the polarizing of primary cells; the formation of this **white sulphate** is technically spoken of as **sulphating.** While the sulphating of undercharging can be partially dissolved by increasing the rate, still the tendency is rather to clear the plate by shaking off the white sulphate with black sulphate, as a sediment, to the bottom of the cell. In addition to sulphating, overcharging produces:

(a) **Buckling:** This is a permanent curvature of the grids due to unequal expansion and may continue until a positive and negative grid touch and the cell becomes short-circuited, with instantaneous and ruinous discharge. (b) **Excessive gassing:** The boiling or ebullition is not a heat phenomenon, it is merely the escape of gas, mainly hydrogen; its deleterious property is the throwing out of the electrolyte in spray, decreasing its level and likely to expose the grids to the action of the air. (c) **Sulphating between the plugs** (active material) **and the containing grid**—this insulates the plugs, is practically insoluble, and assists in unequal expansion to cause buckling.

3. **The battery should be charged at the normal rate,** for which a good rule is to allow 8 amperes per square foot of plate; but this refers to the current at starting; for, constant current, while a good method, takes twice as long as constant voltage.

4. **The battery should be charged at proper voltage, to rated voltage per cell, and at rated time interval.** The voltage to be used is 2.6 to 2.7 volts per cell; for 30 cells, 79 or 80 volts will be the total voltage to be maintained across the battery terminals; under these conditions the battery will have received 50 per cent of its total charge at the end of the first hour, 75 per cent at the end of the second hour, and 83 per cent at the end of the third hour, the remaining 17 per cent will probably be received in another half hour. Completed charging is indicated when each cell shows an individual voltage of 2.5 volts (or as rated) **and no rise of voltage has taken place in the period of 30 minutes.** The "8-hour rate" of charge and discharge is that contemplated for batteries of laboratories, but the "4-hour rate" or less is usual for submarine and launch batteries, the grids being especially spun to prolong the life of the cells for the more severe service.

Any attempt to hurry the charging of a battery, technically **pounding,** will result in occasioning shortened life through rapid deterioration of the grids as well as resulting in loss of energy; under best working conditions in practice a storage battery cannot be expected to show a greater efficiency than 70 per cent.

5. **Do not over-discharge.** The effects of sulphating and buckling are much enhanced by a violation of this principle; the loss from sediment is also increased. The normal rate of discharge is, generally speaking, about 6 amperes per square foot of plate. The limit of discharge is when the voltage per cell is 1.75 and corresponds to a reduction of the total charge to about one-third of its original value.

6. **Do not allow the battery to stand completely discharged, nor its temperature to exceed 100 degrees F.** If it is not possible to full-charge it at once, then a partial charge must be given and **the charge completed before any discharge is again taken.** Rise in temperature decreases the capacity of the battery (about one-half per cent for each degree rise) and increases its internal resistance; the rise is due to the Joule effect, the current set up by local action between the active material and the support plate, the current set up by local action in the plugs, and the heat losses corresponding to the electrolysis of the solution. Heating is the usual result of abnormal charging and discharging.

7. **Keep the electrolyte at the proper specific gravity and at the proper height above the top of the plates.** The top of the grids should be one-half to three-quarters of an inch below the surface of the electrolyte. A curve of densities is practicable for variations in percentage of the charge, and comparison with the actual as shown by the hydrometer during charging and discharge will show whether water or electrolyte is to be added; these are introduced at the bottom of the cell, the gassing acting as an automatic stirrer.

8. **Keep the cells free from dirt and all foreign substances.** It is probable that lead alone of all the metals forms a sulphate that is practically insoluble and unacted upon in water and dilute sulphuric acid; lead also combines with oxygen to form a peroxide, having a good electrical produc-

tivity and equally unaffected by the liquid; hence all other metals must be rigorously excluded.

Nitrogen compounds, especially ammonia, have a seriously deleterious effect on the durability, efficiency, and behavior of storage batteries. Ammonia is found to cause an excessive disintegration or shedding of active material at the PbO_2 plate; it becomes deposited upon the negative plate and closes the pores of the active material, causing a decrease in ampere-hour efficiency of from 10 to 60 per cent in 12 months. The use of water from the boilers and termed "distilled" is a meretricious practice.

Salt water in the cell occasions in the chemical action a liberal evolution of chlorine gas; this is an especially bad feature in a submarine, from its effect on personnel.

A species of "dirt" requiring especial attention is **the crust** from crystallization from the electrolyte, and dust, which forms on the upper, inner side of the containing vessel, creating an excess loss of electrolyte through capillary attraction and subsequent evaporation.

Another form is **the sediment** deposited under even best working conditions by scaling from the plates; the deposit is greatest in amount near the center of the cell, and, being a conductor, can short-circuit the cell if it touches two plates of opposite polarity. It should be carefully raked out with a hard wood or hard rubber hoe—no metal in the construction—then scooped out of the cell; in submarines, however, it is usually necessary to draw off the electrolyte and flush out the sediment. It is very careless to allow sediment to touch the plate.

Another form of dirt is the formation of **lead trees** between the plates, producing a ready thoroughfare for short-circuiting. Inspection should, therefore, include a careful examination for lead trees between each plate and their removal by a thin wand of hard wood or hard rubber.

9. **Keep the battery and all connections clean; keep all bolted connections tight.** Evidently cleanliness and brightness and tightness of connections reduce circuit losses in resistances to minimum.

10. **If there are any low cells in a battery, do not delay in locating and repairing them.**

Each cell is expected to produce the same E. M. F. as every other cell. If it does not it should be cut out, examined for short circuit or other cause, repaired even to returning to the manufacturer, and charged to the individual voltage of the other cells before being again connected in.

11. **Do not charge the battery too frequently.** The greatest wear on the plates occurs during the final part of a charge. When a battery has been discharged one-half or two-thirds its capacity, charging should begin in an hour. If the battery is in daily or frequent use, and only small discharges are made, use one-half the total battery charge before commencing to charge again.

If the discharges are infrequent and not sufficient to amount to one-half full charge in a week, recharge to full charge once a week; a battery which stands idle for some little time can seldom regain its charge by merely recharging; if full capacity is desired the battery should be discharged and

this followed by a full charge. All storage batteries automatically and slowly discharge, due to local action.

12. **A new battery should be set up and filled with electrolyte as soon as practicable.** It should then be given an initial charge in at least 12 cycles, charging and discharging, at a reduced time rate, the operation requiring about 144 hours—about 160 hours if not continuous. A battery does not reach best working conditions until it has had about 20 cycles. The initial charge of a battery that has been placed out of commission is to be given in the same way as if a new battery.

13. **To place a battery out of commission:**

(a) First charge the battery fully, no matter what the charge it already contains, and see that all cells are in condition.

(b) Next siphon off the electrolyte immediately filling the cell with water to the usual height of the electrolyte. This removes surplus acid from the plates.

(c) Discharge the battery slowly until it tests about one volt per cell.

(d) Then take out the plates and allow them to dry.

If the negatives become hot enough to steam they should be again rinsed or sprinkled with clean water and allowed to dry thoroughly; when dry the **negatives** should be replaced in electrolyte of 1.275 to 1.300 specific gravity and allowed to soak for three or four hours; after rinsing and drying again they are ready to be put away.

14. When the plates are in the vessel, whether the cell be filled with electrolyte or water or not, they should be securely chocked to prevent any swinging that would tear them away from the hangers.

The Cadmium Test.—The maintenance of the voltage and consequently the capacity of the cell depends on both the positive and negative plates and, therefore, if one be fully charged or fully reduced, and the other imperfectly charged, the capacity is small, being equal only to that of the least efficient plate; the battery is quickly discharged, and the voltage curve falls rapidly. It is necessary that both the positive and negative elements should be completely charged. The voltage of the battery is not always an indication of the state of charge, and in order to determine the condition of the two plates, it is necessary to test them independently. This is done by immersing a piece of metal, either zinc or cadmium, in the electrolyte and observing the voltage between it, and the positive and negative elements. Zinc is hardly used at all now, owing to the fact that pure zinc is difficult to obtain, and it is soluble in the electrolyte when impure. If any portion be dissolved it has a tendency to deposit during charge on the negative plate and erroneous readings would therefore result.

In using cadmium, which also must be free from marked impurities, the surface of the metal should never be scraped bright, but it should be "aged," that is, slightly oxidized. The reason for this is, that there is a difference of potential between bright cadmium and cadmium oxide, and the bright surface oxidizes so quickly that it would be necessary to scrape the test piece after each reading. The cadmium must not come in contact with any of the plates or connections and the best way to obviate the possi-

bility of such contact, is to cover it with rubber and perforate the covering with numerous small holes.

When a battery is discharged, that is, down to 1.8 volts, the voltage between the cadmium test piece and the positive plate should be about 2.05 and between the cadmium and the negative plate .25, the cadmium being positive to both the elements in the voltaic sense. The voltage of the cell equals 2.05 minus .25 equals 1.8, the cadmium negative reading being subtracted from the positive reading, when both readings are in the same direction. These readings must be made while the cell is discharging at normal rate.

When the battery is full charged, and the normal charging current is still passing in, the voltage between the cadmium and the positive plate should be about 2.35 and the voltage between the cadmium and the negative .18 to .20, the cadmium being positive to the positive plate and negative to the negative plate; that is to say, voltaically considered, the nega-

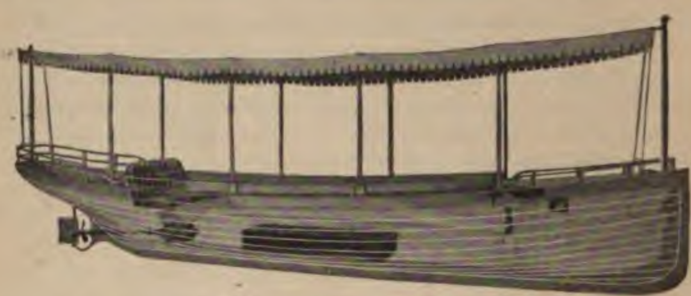


FIG. 204.—Arrangement of boat equipment (commercial).

tive plate becomes more highly electro-positive and instead of being negative to the cadmium, as when discharged, it becomes positive to it.

At the end of the discharge, the cadmium is positive to the peroxide plate, the voltage between them being about 2.05. It is also positive to the sponge lead plate, the voltage between these two being about .25. The voltage between the plates is obviously the difference of the cadmium readings which is 1.8.

At the end of the charging the cadmium is still positive to the peroxide plate, and the potential difference between them has increased. The sponge lead element has changed so that the cadmium is no longer positive to it, but negative. The voltage between the cadmium and positive is 2.32; between cadmium and negative—reading in the opposite direction, however—.18; and the voltage between the plates is the sum of these two, or 2.5. In making all three readings, the sum or the difference of the two cadmium readings as the case may be, should be equal to the observed voltage of the cell, though it is somewhat difficult in practice to measure these voltages accurately enough to make them check exactly, because of the small deflection produced between the cadmium and the negative plate.

Instances have come under observation where cells on charge have shown as high as 2.5 volts and the reading between the cadmium and negative plates practically zero, showing that though the positives were fully charged the negatives were not, and these cells showed little or no capacity. On continuing the charging current for some time, the negatives were finally reduced to lead sponge and the battery then showed full capacity.]

Propelling Electric Launches.

The installation for a 33-foot launch is illustrated in the phantom cut of Fig. 204, which is that for a commercial type of 30-foot cutter requiring 48 storage battery cells, arranged in 4 rows of 12 each; the 33-foot launch is provided with 92 cells arranged in 4 rows.

The launch motor is shunt-wound and develops 12 horsepower when driving the propeller at 560 r. p. m. It is direct-connected to the propeller shaft.

The controller is located under the forecastle deck and its cylinder is rotated by a shaft extending through the forecastle compartment bulkhead, the drum carrying the tiller ropes and revolved by the steering wheel is a sleeve on the controller shaft, the hand wheel on the end of the controller shaft retaining the drum in place. The controller connections accomplish on the five ahead positions the following variations of power, endurance, and propeller speed:

Position.	Volts.	Amp.	No. Hours to Run.	R. P. M.
1	50	26½	35 to 40	274
2	99	25½	22	345
3	99	38	14	415
4	194	41	6	526
5	190	60	Spurting only.	595

The third position is the normal and proper position for operation, and the boat should be stopped when the voltage falls in running to 78 by voltmeter. Position 1 will be evidently for a multiple arrangement of battery of 4 in parallel and 23 in series; positions 2 and 3 for 46 in series and 2 in parallel; and positions 4 and 5 for 92 in series, the difference between them being for difference of resistance in the armature circuit.

The controller being thus arranged for changing the connections of the cells as to the number in series or in parallel, the battery can be charged through the controller as a switch by setting

the controller, at the desirable position. This is position 2 for a 110-volt or 125-volt source. The connection for the charging source is through a special plug switch in the forecastle compartment.

To imform the coxswain as to the current of discharge and remaining total voltage, an ammeter and voltmeter are installed inside the forecastle bulkhead, their scales showing through glass-covered ports.

The battery used is of the Exide type, a form of pasted plate, in which the positive grid has its vertical ribs spaced unevenly, the ribs bringing closer together on the side away from the terminal lug. This is to give better conductivity at points farthest from the terminal and to effect even distribution of current over the plate surface. The cells are small but, with the exception of the smaller capacity, they follow the general rules of storage batteries in Note 25 and furnish an especial example of 11 in that note as follows: *Do not charge too frequently.* If with a battery that will run the launch 40 miles, the launch is run 5 miles, then charged; taken out again, run 10 miles, and charged; given another run of 10 miles and charged, and a third time run of 10 miles and charged again, the launch has run but 35 miles and been charged three times more than necessary, and, moreover, the battery has been strained owing to three unnecessary effects at the final part of charging; that is, it has had three unnecessary and important deteriorating stresses.

The launch type of cells are constructed with a view to the rapid time rate of charging and discharging of 5 hours and for that reason, if it is desired to hurry the charge of, or pound, the battery in emergency, it can be done, provided the shortening of the time is done in the first half of the charging; *the last half must be done at the normal rate* (see II, Note 25). As the cells are tightly covered they are freer from access of dirt and foreign matter, and salt water is mainly to be guarded against. If it gets in a cell the cell must be emptied and refilled with electrolyte, as the Exide cell is very subject to heat effects. Keeping the controller contacts bright with sandpaper and watching minimum voltage are the other chief concerns outside of usual battery care and management.

Motor Generator.

In general, a motor generator is a generating set in which the drive is by electric motor, and as a rule the generator and motor are separate and direct-connected. Ordinarily the dynamotor or rotary transformer is included in the motor-generator classification, although the dynamo and motor are combined in one device.

The utility of the motor generator in conserving energy has already been explained in Note 24.

There are five types in use in the Naval Service: The motor generator for turret-turning or gun-elevating; the motor generator for wireless; the dynamotor, or rotary transformer; the balancer and the rotary compensator.

FIG. 205.—Motor generator for turret-turning and gun-elevating.

Motor Generator for Turret-Turning or Gun-Elevating.— This apparatus, shown in Fig. 205, is of the enclosed armored type, but is of the typical motor-generator arrangement, as shown for the motor generator for wireless (Fig. 206).

The motor generator differs in k. w. output for the class of service for which it is to be used (turret-turning or gun-elevating), but has the same output voltage at the generator terminals as that of the supply line, 125 volts. The motor construction and generator construction, within the same case, follow that previously described for the turret-turning motor .

The connections for starting the motor end and for taking off supply to the turret-turning or gun-elevating motors are shown in Figs. 147 and 160.

Motor Generator for Wireless.—This combination is shown in Fig. 206, and has not thus far been supplied in an enclosed form. The essential difference in this machine and that of Fig. 205 is that the voltage generated by its dynamo is alternating.

There are a number of sizes, but that usually supplied a vessel is of 2 to 3 k. w. capacity, at 65 volts and 60 cycles.

The type is for supplying the primaries of wireless transmitters.

The Dynamotor.—This apparatus is used for supplying the voltage for call bell and general alarm circuits in lieu of primary batteries.

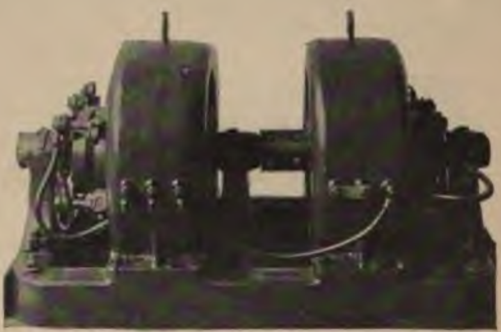


FIG. 206.—Motor generator for wireless: generating alternating current.

[NOTE 26.—The distinction between the dynamotor and motor generator is that the motor dynamo has **a separate field** for its motor and its dynamo, two fields and two armatures, while the dynamotor has **both the motor and armature windings on the same armature core, requiring a single field only.** The primary armature winding, which gives the motor action to drive the machine, is first wound into the slots. The secondary winding which gives the generator action to produce the new voltage, is wound in over the motor winding and in the same slots. The magnetic effects and armature reactions of one winding thus neutralize those of the other, outside strains on the shaft are eliminated, the duty on the bearings is reduced, and the energy which is required in the motor generator for energizing a second set of fields is saved. Dynamotors are more efficient than motor generators; have no tendency to spark; there is no occasion for moving the brushes for varying loads since the line of commutation does not shift due to the fact that the armature reaction produced by the motor winding is opposite in effect to that of the dynamo winding. They can in consequence stand a greater overload than motor generators, but their E. M. F. drops because they cannot be compound wound to compensate for the slowing down and for the resistance of the winding.

The ratio of transformation of dynamotors cannot be varied or adjusted, ince both windings are on the same core and under the influence of the ame field. Any adjustment of field strength (as usually employed on a ynamo) will simply make them run faster or slower. As the ratio of the urns on the dynamo end to those on the motor end is unchangeable, the oltages at the two ends will remain in the same ratio. Therefore, **when t is desired to vary the voltage** to be given out by the dynamo, a motor enerator* (motor dynamo), a double field machine, is mandatory in order hat its dynamo windings may be on a separate core and magnetized by a eparate field.]

The type of dynamotor in use (Fig. 207) is known as the ¼-orsepower size, has a speed of 1800 r. p. m., and takes, at the notor end, an input of 2.5 to 4.0 amperes at 80 volts, transforming to 80 watts, at 20 volts, at the dynamo terminals; 20 volts

FIG. 207.—Latest type of dynamotor.

being the operating voltage for general alarm gongs. The number of brushes for the dynamo end are but two in the original design, 180 degrees apart; it was found that two extra brushes, tapping off 13.3 volts and 6.6 volts could be added without sparking and this arrangement is now often followed for the main call-bell lines (13 volts) and call bells for quarters (6 volts).

The Balancer.—This apparatus is similar in its general construction to the motor generator of Fig. 205, except that its motor is series-wound. It is supplied in supersession of the search-light rheostat to avoid the large loss in heat; for if the rheostat were used with the 60-inch lamp, for instance, the energy consumed would be 125 volts $\times$ 200 amperes $=$ 25 k. w., of which the lamp only requires 60 $\times$ 200 $=$ 12 k. w., the remaining 3 k. w. being wasted in heat in the rheostat, including a small mount in the circuit.

The scheme of operation can be understood from the ele tary diagrams of Fig. 208.

In the upper diagram the connections are shown, inclu the starting rheostat, which is between the dynamo armatur and the negative current supply line. The shunts on the s field windings are for the purpose of adjustment in manufact The paths of current flow, before the arc is struck, are as i cated by the arrow heads. The dynamo D is excited by a sh field across the current supply leads, and in this initial condit

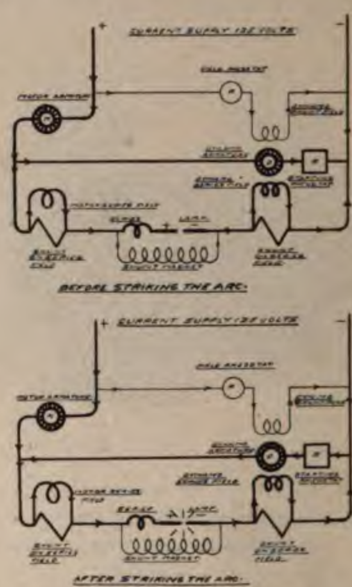


FIG. 208.—Elementary diagram of balancer.

operates as a motor, driving the motor armature M, which the same shaft. It will be noted that there is but a slight cu in the two series fields, owing to the resistance of the shunt net coils of the projector lamp, which is in circuit, and the low resistance of the motor armature, the carbons being sepa This current in the series fields of the dynamo and motor small to affect the conditions. The shunt magnet coils c lamp have practically full line voltage on their terminals, consequently, actively operate the mechanism feeding the ca together.

As soon as they come in contact, the arc-striking magnet coils in series with the carbons are excited and separating the carbons "strikes the arc." The current flow is now indicated in the lower diagram.

The current flow in the series coil of the dynamo now opposes the excitation of the shunt field reducing the magnetism and causing the counter electromotive force to be lowered. At the same time, however, the same current flow in the series field of the motor, causes its armature to become an active factor, and its counter electromotive force replaces that of the dynamo, which no longer acts as a motor.

As the carbons burn apart, the length and resistance of the arc increase, causing a weakening of the series field on the motor which causes it to speed up. There is also a weakening of the differential series field of the dynamo, which allows the shunt field to become relatively more active. These two effects tend to increase the voltage, and cause the shunt magnet coils of the lamp to operate to bring the carbons together to their normal distance of separation and to increase the current in the arc.

In the case of too short an arc, from any cause, the excess of current will cause the motor to slow down, and the differential effect of the series coil on the dynamo field will lower its voltage.

The shunt-field rheostat gives a means of compensating for the variations in operation, such as cool or warm windings on the motor, dynamo, or lamp.

The particular feature of the balancer is the opposing of the excess of line voltage, by counter E. M. F. of the armature of a series-wound motor in series with the lamp; and the generation of an increment of current supply by the E. M. F. of the armature of a differentially compound-wound dynamo which, added to that furnished by the supply lines, is sufficient for the operation of the lamp.

The special features of transfer of motor function in starting, of generation of the necessary increment of current, and of automatic regulation in operation, constitute a very unique and satisfactory system of control.

The Rotary Compensator.—This is the most recent combination of a motor generator for turret-turning whose object is to farther reduce the slow speed of the turret as obtained by the

series connection of the turret motors, described in Note 24, and as there stated about 6 degrees per minute minimum.

For the purposes of the rotary compensator the turret has one large motor and one small motor (of about one-fifth the horse-power of the large), instead of two large motors.

A magnetic clutch and gearing is so arranged that the turret can be turned by the small motor alone from *about ¼ degree to 4 degrees per minute.* The large motor is directly connected to the gearing of the turret and will turn it from about 5 degrees to

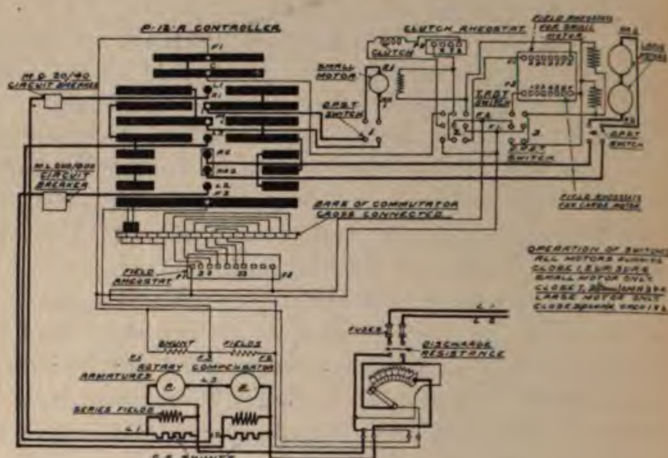


FIG. 209.—Connections for turret-turning using rotary compensator (thr turning motors shown).

100 degrees per minute. The armature connections of the lar motor are not made until the small motor has brought the turr up to the minimum speed at which the large motor will turn at which time the clutch is released and the large motor turns t turret. For convenience, both the large and small motors a arranged to have some field control, permitting the turret to turned by the small motor up to a maximum speed of about 6 degrees per minute, and by the large motor down to about 4 degrees per minute when either motor is running alone.

The rotary compensator whose connection to the motors shown in Fig. 209, while similar in appearance to a motor gen

ator, is quite different in its action. It consists of two armatures mounted upon one shaft and turning in two separate magnetic fields. The armatures are connected in series and the shunt-field windings are also in series.

[NOTE 27.—Fig. 209 really shows the arrangement as now applied to vessels which already have two motors installed for turning each of their turrets; in an *original* installation but one large and one small motor are to be installed.]

A rheostat is placed in shunt with the two fields, which are in series, the center of the rheostat arm being connected to the junction of the shunt fields. When this arm is turned to short-circuit, the shunt field of the armature in multiple with the small motor, there will be practically no difference of potential across the armature terminals, but the other armature will be operating, in a full field at maximum voltage. As the arm is gradually moved across the rheostat, the resistance in multiple with the first field increased, causing the field to strengthen, while the resistance in multiple with the second field decreases, reducing its field current and correspondingly reducing the voltage across the terminals.

When both motor circuits are opened, the current necessary to drive the set light passes through the two armatures in series, but when one of the motors is loaded the amount of current which it takes depends upon the voltage obtained upon the field of the armature with which it is in multiple. The current for this motor is, therefore, derived partly through the other armature and partly from the armature with which it is in multiple, which may be acting as a generator.

If the motor is running at very low voltage, the current required may be considerably more than would be necessary to drive the set, and also drive the armature with which it is in multiple, which latter would then generate sufficient current to make up the difference; but if the motor is running at practically full voltage, then probably all of the current will come from the line, through the other armature, and none will be generated by the armature in multiple with the motor.

It will be noted that the set is similar to two separate generators, each running its own motor, but which differs in that some

of the current is always taken from the line. It has a considerable advantage over the motor generator set in the design of the controller, since a change in the shunt resistance affects both the fields, and in this design this means a very large increase in the number of speeds obtainable without a large increase in the number of rheostat leads.

The field contacts of the controller are made on the end of the commutator which is so cross-connected that, as the contact brush passes over the contacts, it brings the voltage of the small motor to a maximum when it has passed through half of its motion (at which time the voltage of the large motor is minimum) and then reverses the operation during the other half of its travel, bringing the large motor to a maximum, and the small motor to a minimum speed. A carbon brush is used for making contact with the commutator above described, whose resistance gives a multiplying effect, and thus furnishes a much smoother acceleration curve than would be obtained under ordinary circumstances.

CHAPTER X.

'HE INSPECTION OF GENERATING SETS AND MOTORS.

Generating Sets.

'o avoid loss of time and labor and to accommodate the tests :he prescribed navy yard hours for employees, the inspection compliance with the specifications is divided into three stages: :liminary Inspection, Preliminary Test, and Final Test. roughout the inspection all features peculiar to the design, all idents of operation, and every departure from the specifications noted minutely as they have an important bearing on the final isideration as to acceptance.

mmediately before the test the voltmeters, ammeters, tachom-rs, hand counters, and indicators are calibrated by the stand-s and the factor expressing their accuracy is noted on the t sheets. Thermometers should also be checked; it is found ivenient to use the centigrade instruments.

'reliminary Inspection.—The weight is first taken. The gen-ting set is then set up on an iron test plate, on a heavy founda-1, to insure against vibration. The section of the test plate embles an assembly of closely placed railway rails; under the iges are slipped the heads of large square-headed bolts, the :s being set up on iron dogs so placed on the generating set l-plate as to hold the set securely.

The preliminary inspection can be held while the set is being ied up, its object being to examine into all the details of dimen-ns and mechanical construction required by the specifications, in accordance with the dictates of good, up-to-date engineering d electrical practice and workmanship, which can be investigated

without deranging the assembly and adjustments as made by the contractor; all items necessarily omitted at this time are investigated by taking the set apart after the final test. Where doubts arise as to the material employed recourse is had to the drawings, and, if necessary, to the advisable chemical or physical test. *A case has occurred in which a cross-head was found to have been made of cast iron.* It is the intention of the specifications to produce a generating set which shall be first class in every particular of design, construction, or operation. Any omission from the specifications of any part of the machinery necessary to produce the result, or failure to describe the design and construction does not operate to release the contractor from supplying such part of the machinery, or from performing such work as part of his contract without additional expense to the Government.

As all items of mechanical construction are entered into at length in official specifications, attention is called only to the following, which require explanation:

1. *The general appearance of the set resulting from design must be of the highest character.* This item includes details and working parts together with the general make-up and finish of all. Nice finish and appearance supply the incentive for future care and attention.

2. *The standard sizes, with their corresponding maximum allowable speeds, weights, and overall dimensions are* (see table, page 163): The length and width are measured between the four vertical planes which would enclose the set; the height is measured from the lower edge of the bed-plate (or from the lower edge of the dynamo frame if the frame dips below the bed-plate) to the horizontal plane across the top of the cylinder covers, or across any self-contained connections projecting over the cylinders, such as bolt heads. It is common in investigating this item to find excesses in dimensions, especially in length, and in the prescribed weight; they afford fruitful sources for the consideration of waivers, and are antagonistic in their effect on design.

3. *The design must afford accessibility to all parts usually requiring inspection under operation, or adjustment when under repair.* The general idea is to prevent crowding and complication of parts.

4. *The driving shaft to be fitted with thrust collars or other*

suitable device which will prevent a movement of the shaft in the direction of its length, due to magnetic drag or the pitching or rolling of the ship. The dynamo armature will then remain central in its field as regards motion in the direction of the axis of the shaft.

5. *The driving is to be effected by a cross key set in the coupling faces.* This is a precaution against looseness and lost motion at the coupling; the cross key is to relieve the coupling bolts of the driving stress and prevent strain.

6. *The engine cranks are not to dip into the oil in the reservoir.* This has two distinct advantages: it permits a clear view of the cranks while running, and prevents churning the oil to a lather inside of the casing. The item includes counterweights, when placed opposite the crank.

7. *Relief valves, in addition to the drains, to be fitted to each end of each cylinder; their seats to relieve the cylinder of water.* It is important that the relief valve springs be non-corrosive.

8. *The length of the stroke of the engine is not to be less than the diameter of the bore of the high-pressure cylinder.* This keeps the per cent of clearance within good limits, and prevents the altering of this percentage by so small a mechanical clearance distance as will be dangerous in operaton.

9. *Stuffing boxes for piston rods and valve rods must be accessible from the outside of the engine casing.* If the stuffing boxes are put in on a driven fit, an arrangement for locking must be provided or the boxes will turn.

10. *A guard plate is to be provided to prevent throwing of oil against the lower cylinder heads and lower ends of the valve chests.* This item applies to those constructions in which the lower cylinder head or the lower end of the valve chest is exposed to the inside of the casing. The oil thrown against these lower ends not only produces a cooling effect but will carbonize and drop as grit on the moving parts and work into the journals.

11. *The method of securing the lagging must provide for its ready removal, repair, and replacing.* It is important that the surfaces concealed by lagging should be inspected for defects in casting or joints.

12. *Blank flanges are to be supplied for the alternative outlets.* One steam outlet at the end is the common practice; two outlets for exhaust are necessary.

13. *Piston rods must be securely fastened to the cross-head.* The common practice of fitting the rod to the piston end is a taper turn with shoulder, set up by nut and jam nut, the jam nut being secured from turning on the thread by a split pin. A screw and clamp connection at the cross-head end is very objectionable and is quite sure to work loose.

14. *The shunt and series windings of each field coil are to be separately mounted on the field core.* The intention is that they shall not be wound in combination, one over the other, on the same spool, but shall slip on and off separately.

15. *The bolts holding the armature core not to pass through the discs.* The governing principles of the construction of an armature core are: that it shall drive well without mechanical strains; to avoid Foucault currents which would heat the core and raise the temperature and resistance of the winding (which would in turn cause more heat); to afford such good ventilation as will carry off heat and keep the core and winding cool.

16. *The commutator bars to be securely clamped by bolts and clamping rings.* This should assure the prevention of the occasional case of unevenness in the bars, or sluing out of parallelism with the shaft, occurring from light force or pressure.

17. *The brush-holders are to be staggered.* In order that the wear may be evenly distributed over the entire range of the commutator surface.

18. *Make the following examinations:* Interior of cylinder and valve chests for fins, scales, sand, and foreign matter or tools that may have been left in the ports or in the interior.

Interior and bottom of casing for core sand, and foreign matter which will drop on the working parts or mix with the oil in the reservoir.

That all bolts and nuts are tight and secure.

That there are no scores or abrasions of the cylinder and valve chest surfaces to permit leakage of steam past the valve or piston.

That all generator connections are bright, tight, and secure and the interior of the core, surface of windings and fields, and commutator are clear of dirt and grit.

Preliminary Test.—The object of this stage is to test items which require only a short run of the generating set; to assure the general readiness of the set for the final test; and to make any

necessary adjustments, such as for speed, compounding, or engine regulation.

1. *Cold Resistance of Armature, Series, and Shunt Fields.*—Just before starting the set, the cold resistances of the armature, series and shunt windings, and the temperature of the air, are measured as a check on those to be taken before the heat run of the final test. Accuracy of cold resistances is very essential; with the small differences in resistances obtained for the armature and series windings for the calculation of heat rise, the low resistances of the armature and series windings, and the haste necessary in measuring the hot resistances, accuracy in cold resistance is the main dependence.

2. *Insulation Resistance (Ohmic).*—The insulation resistance of windings is least when hot, and is measured cold in this stage for the purpose of developing any injury which may have occurred during shipment, or by the absorption of moisture; the moisture can be dried out either under load or by baking at a low temperature.

A 500-volt storage battery is connected to the switchboard leads, to which are connected two flexible leads having a 500-scale voltmeter in circuit. The insulation resistance is then taken by the Voltmeter Test. The insulation resistance should be a megohm for the following measurements:

Armature winding to shaft.
Series winding to shunt winding.
Shunt winding to magnet frame.
Each brush-holder to rocker.
Positive brush-holder to negative brush-holder (brushes up).

If low insulation resistance develops in either field each coil of each field is tested out separately.

3. *a. The Armature is to Run True.*—After a trial run to ensure that all parts are working properly the engine is brought to full speed. The armature and crank shafts are gauged by a machinist's surface gauge, secured at any convenient point, to develop that the shafts are true and central in their bearings. The commutator is then similarly gauged to determine that it is concentric with the shaft.

b. The Armature is to be Balanced Mechanically.—This is tested by placing graduated wedges between each pole piece and

the armature surface and taking measurements at the edges of the pole pieces while revolving the armature by hand.

c. The Armature is to be Balanced Electrically.—An armature which does not run true and is out of balance mechanically or magnetically will not run smoothly and without vibration, and will heat and spark from the inequality of the currents generated in the different sections of the armature. Separate excitation is preferable in testing magnetic balance as giving a more constant field.

The brushes are first examined for good contact on the commutator, and whatever trimming or dressing is required is done at this period of the inspection.

The brushes are first spaced equally all around the commutator, the toe of each brush being brought to line marks which are equally spaced on a strip of paper laid closely around the commutator.

The generator is run without load and the shunt field separately excited. The voltages between consecutive pairs of brushes are then measured separately for each pair, all brushes except the pair under measurement being at that time off the commutator. The admissible variation in voltage for any two pairs of brushes is one volt; if greater than one volt, the field frame must be adjusted to bring the armature magnetically central in the field, due care being exercised as to the mechanical clearance. Measurements by voltmeter are not applicable if the armature is cross-connected, and mechanical measurements of air gap under each pole, with the field both on and off, are employed instead; it can be accurately accomplished by graduated wedges. If faulty, the resistances of the various field coils should be separately measured to ascertain if the fault is due to differences in their construction.

It is useless to test electrically for magnetic balance if the armature is provided with equalizing rings.

4. *The Generator is Next Connected Up for a Short Operation under Various Stages of Load.*—The load is applied gradually, the effects on working parts, oiling system, etc., are noted, and particularly the stability of the voltage and the sparking. With a new machine the voltage will frequently not be maintained, due to a weak field, arising from opposition of the series and shunt fields or from one or more reversed coils; if not due to these causes the field is weak in original design and unsatisfactory.

A weak field will produce excessive sparking in as much as the armature current will cause greater distortion of field and consequent farther shifting of the neutral point; shifting the brushes may correct the sparking but the voltage will drop.

5. *Compounding.*—The compounding test required by the specifications is that for the maximum temperature of the windings after running at full load. The test of this stage, or cold compounding, is for the purpose of checking the action of the series shunt.

6. *Valve Setting and Steam Distribution.*—After the compounding test, the set is run for a short time at normal steam pressure and voltage and a good set of indicator cards obtained for full and no load from which to investigate the distribution of load between the cylinders and the correctness of the valve settings.

7. *Engine Regulation.*—This item is principally for the purpose of testing the governor action. Two readings, breaking from full to no load, and no load to full load, in one step, are all that are necessary.

Observations are made of the effect on, and action of, the various working parts; jump in voltage; ability to maintain rated voltage; sparking; tendency to throw oil; sluggishness, racing, and hunting; and general performance. If the governor requires adjustment it is effected by the methods explained for the different types of generating sets; after adjustment the regulation is again tested.

8. *Operation on Overload.*—The load is raised to one-third overload, for a short run, to test the strength of the working parts, to observe any sparking or flashing, and that the speed and voltage are maintained under the condition.

Final Test.—The third stage is to be exhaustive of specifications as to operation of both engine and generator, and as to all mechanical provisions omitted in the preliminary inspection. All reasonable adjustments having been effected in the preliminary test no others are permitted.

An interval of twenty-four hours should elapse between the preliminary tests and the final tests in order that the generator windings, which had been heated under load, may cool down to the temperature of the surrounding air, and in order that the heat run may not start with an initial heat rise in the windings.

To determine what, if any, initial rise exists, thermometers are placed (and protected from draughts) on the commutator, armature core, and within the field coils. Their temperatures are then compared with that of the surrounding air; the comparison is preferably made with the temperature shown by a thermometer which has been placed on the armature core of an adjacent idle machine, as its temperature represents more accurately the actual machine conditions.

1. *Measurement of Cold Resistances of Armature, Series Field, and Shunt Field Windings.*

The resistances are measured by the fall of potential, or drop method.

a. Armature Winding.—The fall of potential is taken between two appropriately selected commutator bars. The distance of these two bars apart, counted by bars around the periphery of the commutator, depends upon the number of poles; for a 4-pole generator the distance is one-fourth the total number of bars; for a 6-pole, it is either one-sixth or one-half; for an 8-pole, it is one-eighth or three-eighths. In the optional cases, that parallel combination of the total winding is taken which will give the higher resistance; for example, in a 6-pole machine one-half the total number of bars, in an 8-pole, three-eighths. It is not the working resistance of the armature which is desired but a sufficiently representative integral resistance, and it is sufficient to take the resistance between any two bars which are conveniently located under brushes of opposite sign. In case the generator has an *odd number of pairs of poles* these bars should be taken as nearly diametrically opposite as possible; if the total number of bars be even, the bars can be chosen exactly so. With an *even number of pairs of poles* the bars are chosen at a distance apart which is as nearly as possible some exact fraction of the total, care being taken that the selected bars come under brushes of opposite polarity; if it be more convenient the intervening distance can be exactly that between two consecutive sets of brushes.

It is necessary that the same bars be chosen for both the hot and cold resistance and to ensure it the selected bars are marked on the end by a small hand drill; the use of a center punch may start the bar and produce unevenness in the commutator.

To ensure that the current flows only in the two bars which

were marked by the drill, all brushes are lifted except those over the two marked bars. If the generator has a number of brushes per stud but one brush is used at each bar.

A strip of copper is laid on each punched bar and must be narrower than the bar to make good contact; the brush is then placed in contact with this strip. If the copper strip should cover more than one bar the current will flow through the armature in a very different manner than as above prescribed and the results be erroneous. The use of a small strip of copper under one brush precludes the use of a large current in measuring, but excellent results will be obtained with currents at and below 10 per cent of the rated amperage of the machine.

The armature resistances are taken cold at the start of the heat run, and hot at its completion, in order that the rise in temperature of a winding may be calculated. This method of determining the heat rise is that in long use and adopted by the American Institute of Electrical Engineers, June 20, 1902, for Electrical Generators, Motors, and Transformers, in the following citation: (Evidently the average rise only is contemplated, the highest rise being that in the portion of the windings approximately midway between the surface and the core; the lowest is that of the outer or free surface.)

Rise of Temperature.

"**General Principles.**—Under regular service conditions, the temperature of electrical machinery should never be allowed to remain at a point at which permanent deterioration of its insulating material takes place,

"The rise of temperature should be referred to the standard conditions of a room temperature at 25° C., a barometic pressure of 760 mm., and normal conditions of ventilation; that is, the apparatus under test should neither be exposed to draught nor enclosed, except when expressly specified.

"If the room temperature during the test differs from 25° C., the observed rise of temperature should be corrected by ½ per cent for each degree C. Thus with a room temperature of 35° C., the observed rise of temperature has to be decreased by 5 per cent, and with a room temperature of 15° C., the observed rise of temperature has to be increased by 5 per cent. The thermometer indicating the room temperature should be screened from thermal radiation emitted by heated bodies, or from draughts of air. When it is impracticable to secure normal conditions of ventilation on account of an adjacent engine, or other sources of heat, the thermometer for measuring the air temperature should be placed so as fairly to indicate the temperature which the machine would have if it

were idle, in order that the rise of temperature determined shall be that caused by the operation of the machine.

"In electrical conductors, the rise of temperature should be determined by their increase of resistance where practicable. For this purpose the resistance may be measured either by galvanometer test, or by drop-of-potential method. A temperature coefficient of 0.42 per cent per degrees C., from and at 0° C., may be assumed for copper. By the formula

$$R_t = R_0 (1 + 0.0042t) \text{ and } R_{t+e} = R_0 [1 + 0.0042 (t + e)]$$

Where R_t is the initial resistance at room temperature $t^0 C.$ R_{t+e} is the final resistance at temperature elevation of $e^0 C.$ R_0 is the inferred resistance at $0^0 C.$

These combine into the formula:

$$e = (238.1 + t) \left(\frac{R_{t+e}}{R_t} - 1 \right) \text{degrees } C.$$

"Temperature elevations measured in this way are usually in excess of temperature elevations measured by thermometers.

"When thermometers are applied to the free surface of a machine it is desirable that the bulb of the thermometer should be covered by a pad of definite area. An unduly large pad over the thermometer tends to interfere with the natural liberation of heat from the surface to which the thermometer is applied."

The brush leads are first connected to the main leads to the switchboard, the latter being connected with a storage battery as the current will be more steadily supplied and obviate errors of self-induction. The circuit breakers of the switchboard are closed and the portable rheostat is connected up to supply that resistance in circuit which will adjust the current value; the armature resistance is so small—a small fraction of an ohm—that its resistance, in series with that of the portable rheostat, will have a negligible effect on the resulting current. A portable ammeter whose scale covers at least 10 per cent of the rated amperage is connected in the current leads. A portable voltmeter, 0 to 1.5 scale, is placed on the table and connected up to a standard set of leads, which are fitted with pointed terminals at one end to fit the punch marks, and with terminals at the other end for connecting to the voltmeter. When ready for the measurement a switch is closed on the portable rheostat which will afford approximately 2 to 5 per cent of the rated amperage of the generator. The pointed ends of the standard leads of the voltmeter are then pressed into the punch marks of the two commutator bars and quick, simultaneous readings of the ammeter and voltmeter taken. Exactly similar readings are then taken for two current adjust-

ments of the rheostat which are between that already used and 10 per cent of the rated amperage.

From the three voltages, or drops, and their corresponding currents three resistances are calculated by Ohm's law *and should not differ from each other by more than 1 per cent.*

Notes of Test.—The maximum current should not exceed 10 per cent of the rated amperage of the generator. Excellent results are obtained with small currents provided they are sufficient to give a reliable reading of the voltmeter; large currents will heat the winding and cause erroneous differences in results.

The pointed ends of the standard leads must be applied directly to the punched commutator bars themselves and not to a connection such as a brush-holder, brush, etc.; the injunction applies to an intervening brush, the resistance of carbon being negatively affected by a rise of temperature and thus causing error in the measured resistance.

The closing of the rheostat switch, the connection of the voltmeter to the bars, and simultaneous readings, must be effected with all practical despatch that the winding may be as little affected by the heating action of the current as possible. Break the voltmeter connections by the instrument key before opening or closing the load switch, to avoid injury to the delicate voltmeter by self-induced voltage. The shunt field must be opened at its switch before measuring or its resistance will be in parallel with that of the armature.

b. Series Winding.—The cold resistance of the series windings is measured in the same way as that of the armature; the measured resistance being that of all the series coils, on all poles, in series. The same approximate currents are used as in the test of the armature and are led by the brush leads. The resistance will be much less than that of the armature and a voltmeter of scale 0 to 0.15 is employed. The series shunt must first be disconnected.

The pointed ends of the standard voltmeter leads are held closely to the drill mark, which is to be as close to the end of the series winding proper as possible to avoid other contact resistances.

The precautions are the same in general as those observed in the armature measurement except that the series winding remains in series with that of the armature; the resistance of the latter

does not affect the readings, as the resulting drop is that of the series field only. To ensure good contact at the commutator several brushes should be let down. The three resistances should not differ by more than 1 per cent.

c. Shunt Winding.—The resistance of the shunt winding is, similarly to that of the series, taken for all the coils in series. The drop is comparatively high and will differ from the rated terminal voltage of the generator by from only 10 to 50 volts, according to size and design. The current for ordinary operation is small, and currents are therefore used whose maximum is the operating shunt current and whose minimum is about one-half this value. The load is adjusted by the shunt-field rheostat without the use of other load resistance. All brushes must be raised from the commutator, to avoid paralleling the armature and series windings with the shunt. A 0 to 150-scale voltmeter and a 0 to 15-scale ammeter are employed; they are connected up through flexible leads at the bottom of the switchboard. Adjustments of current are made by operating the shunt rheostat, *which must start with all resistance in when the field switch is closed.*

Precautions.—It is very important that shunt-field resistance readings be taken quickly; the field will heat rapidly under the amount of current used and such heat will have an appreciable effect on the result. The voltmeter must be out of circuit before the field switch is opened and until after it is closed; there is great danger of burning out the voltmeter, due to self-induction, or of bending the needle.

2. *Heat Run at Rated Full Load.*

The heat run is next started and consists of a 4-hour continuous run under full load, at normal steam pressure, rated speed and rated voltage. Its objects are to test the endurance of operation of both engine and generator, and to determine the heat rise of the windings.

When ready to start the set, place a thermometer with its bulb in a line with the center of the shaft and 3 feet from the commutator end of the generator, which will give the air temperature to be recorded and allowed for in each half-hourly computation of resistance. Place a second thermometer on the armature of an idle machine near by. Place a third thermometer on the shunt-field rheostat, protecting its bulb from air draughts.

he generator is connected up, as shown in the elementary diam (Fig. 210); the steam pressure is regulated to the normal, engine started up, the armature brought to rated speed and the uum to 25 inches. The shunt-field switch is closed and the d voltage regulated, meanwhile taking several check readings

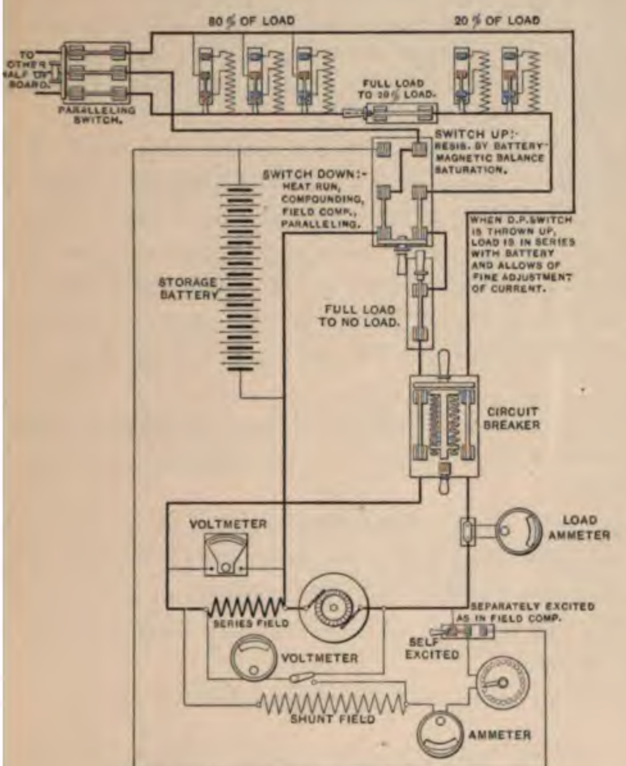


FIG. 210.—Connections of generator for test.

he drop on the shunt field. About 5 minutes later full load hrown on in successive short steps, several check readings the drop on the series field being taken while so doing, the es shunt being for the time disconnected. The field and load ostats are then adjusted for rated voltage and amperage out-, and so maintained throughout the run.

NOTE 28.—The load used in Navy Yard and shop tests differs for rent places and circumstances: for small machines banks of electric

lamps (with as many large lamps as practicable) are used and connected up to be conveniently divided by series and parallel connections into fractional currents; at the New York Navy Yard, the load consists entirely of rheostats of German silver ribbon, giving a capacity of 2000 amperes in series and convenient fractions thereunder; at contractors' works the load is provided mainly by water boxes, though lamp banks are used for lighter loads. The water boxes are plain boxes containing water and 1½ to 2 pounds of salt per cubic foot of water; a fixed plate forms one terminal, the other terminal being a movable plate, which, being adjusted in distance, gives the necessary resistance to adjust the current (load); as the water is evaporated by the boiling of the water in the box more water is added from a convenient tap.]

Readings of terminal volts and amperes, resistance of shunt and series fields, speed, steam pressure, vacuum, temperatures, pressure of lubricating system, etc., are then taken every half-hour. Each half-hour, as the readings are taken, the temperature rise of each field winding is calculated and plotted; these curves afford a convenient insight into the heat action; the trend of the curve at the end will indicate whether the rise has reached constancy.

The armature must maintain rated speed or the shunt field will be unduly heated from the extra current required to maintain the rated voltage.

The amperage of the shunt field is taken by a 0 to 15-scale portable ammeter connected to the flexible leads. When measuring the voltage of the series field, the series shunt is for a moment disconnected and the drop taken by standard leads connected to a portable voltmeter.

The following are the items of observation during the run:

I. The Set Must be Capable of Running:

a. Without Undue Noise.—Noise is an annoying fault on board ship. Whistling and grunting in the cylinders should disappear as the pistons wear smooth; this variety of noise occurs mostly under light loads from insufficient moisture in the steam to afford lubrication in the cylinders. The oil pump will be noisy if not designed with sufficient relief to obviate pulsation of pressure. Noise due to grinding of valves on their seats or to the pistons over-riding the counterbore are to be particularly investigated.

b. Without Undue Heating.—All bearings should run cool,

that is, sufficiently so to permit testing with the hand for a few seconds.

II. The Set Must be Balanced and Run True.

This refers to any tendency to get out of balance or to change from true by wear or alteration of alignment. It is tested by gauging.

III. The Set Must be Capable of Running for Long Periods Under Full Load and Without Continued Attention.

This item is not assured in acceptance tests except in the most general way; the specification refers more particularly to the contract guarantee for six months' operation after installation.

IV. The Driving Shaft Must be Fitted with Thrust Collars or Other Suitable Device which will Prevent a Movement of the Shaft in the Direction of its Length, as Might be Caused by the Rolling or Pitching of the Ship.

The shaft collars should prevent an end play of the shaft of more than ⅛ inch; a play of 1/16 to ⅛ inch is advisable from mechanical considerations.

V. Engines are to be so designed that the Work Done by Each Cylinder, as Shown by the Indicator Cards, will be as Nearly Equal as Practicable Under all Conditions of Load.

A set of indicator cards are taken every hour to verify this condition as well as to examine into the correctness of the valve settings and of the steam distribution.

VI. Engines are to Operate Satisfactorily Without the Use of Lubricants in the Steam Spaces.

The external evidence of insufficient lubrication in these spaces is a whistling or grunting noise. It is infrequent in vertical engines after the piston and valve edges become polished.

VII. The Engine Shall be Capable of Satisfactory Operation with a Low Grade of Lubricating Oil.

The oil used in the test operations consists of two parts of an oil which has been once used and afterwards filtered and one part of clean (new) oil. Arctic engine oil is used for new oil.

VIII. The Lubrication for all Working Surfaces, Other Than Those of Steam Spaces, is to be of the Most Complete Character. No Part Shall Depend on Squirt Can Lubrication.

Forced lubrication is to be used wherever practicable; the intent of forced lubrication is to reduce friction, noise, and attention. The pressure for forced lubrication is to be approximately 15 pounds per square inch, and to be between 10 and 20 pounds under all service conditions.

Grease cups are preferable for the governor-rod journals, journals of the governor assembly, and rockshaft sleeves. The outer pillow-block bearing at the commutator end should be of the ring-oiler type, showing the height of oil by a gauge; it is from this bearing that oil is most likely to flow to the commutator.

The stuffing-box surfaces are sufficiently oiled by that oil which is picked up in the casing by the valve and piston rods.

It is essential that the results of the devices for lubrication be noted in their separate action for each particular part that no fault may be overlooked which can occasion difficulties in service.

IX. The Oil Pump is to Handle Clean Oil Only, not Drawing from the Top or Bottom of the Reservoir.

That is, the receiver of the oil pump is not to be so located as to draw dirty oil from the top or bottom of the oil contained in the well.

X. To Permit Inspection While Running the Engine Crank is not to Dip into the Oil in the Reservoir.

XI. The Generator is to be Capable of Supplying the Rated Voltage at the Terminals when Run at Constant Speed.

XII. The Commutator Bars are to Line with the Shaft and Run True.

True running is tested from time to time by gauge, or by sighting the perimeter with some fixed adjacent object.

XIII. The Armature Shaft is to be Provided with Suitable Means to Prevent Oil from Bearings from Working Along to Armature.

The access of oil to the armature windings or commutator is a

al fault and it is absolutely necessary that no oil should reach : armature whether thrown on or by flow.

V. The Magnetic Leakage at Full Load Shall be Imperceptible at a Horizontal Distance of 15 Feet, Measurements to be Taken with a Horizontal Force Instrument.

This test is made by placing a detector or horizontal force inument at radial distances of 15 feet whilst the field is excited full strength, and noting any variation in deflection of the edle due to stray field. Multipolar constructions will rarely casion any stray field even at a much less distance than 15 feet.

-. The Design is to Eliminate all Chance of Oil or Water Leaking or Being Forced Through Enveloping Enclosures and Hinged Doors.

Defects of this nature occasion the throwing of oil or water on : armature and commutator and are very objectionable.

VI. Any Disposition of the Working Parts to Weakness or to Work Loose or Develop Lost Motion is to be Carefully Noted with Probable Cause.

A particular item of attention is a tendency to change speed le to stretching of the governor spring.

VII. There Shall be no Sparking when Load is Gradually Increased Between No Load and Full Load. (See note 20 and also remarks on sparking.)

As a rule sparking faults will develop in the preliminary tests.

XVIII. Water Consumption.

The normal steam pressure under which the engine, running ondensing with 25-inch vacuum, for different sized sets, is to perate, and the maximum allowable water consumption per k. w. our output of the set are:

K. W.	Normal steam pressure.	Water consumption per K. W. hour full load.
2.5	100	105
5	100	90
8	100	65
16	100	44
24	100	40
32	100	37
50	100	35.5
50	150	33.5
100	150	31

Corrections are made by calorimeter for entrained moisture. Superheating must not be used in the test.

The test is made during the last hour of the heat run in order to accommodate the working of the boilers.

Dry steam only is wanted and precautions must be taken to reduce the percentage of moisture carried over from the boiler; the branch steam pipe is to be lagged close up to the engine and the fireman notified to keep the water in the boilers at a constant level during the test, the level to be as low as is compatible with safety to the boilers.

A Carpenter Separating Calorimeter is tapped into the branch steam pipe as near the engine as practicable. The calorimeter consists of a small steam separator through which a sample of the steam supplied to the engine is passed and by which the moisture contained in the steam is removed; the dry steam flows on and is condensed into a can of cool water. A glass water gauge attached to the separator has a scale which reads the amount of water in the separator directly in tenths and hundredths of a pound; a similar gauge on the cooling can reads the weight of dry steam condensed. The quality of the steam is obtained by adding to the weight of the dry steam condensed during some convenient period of time, generally 10 minutes, the weight of moisture entrained in the separator during the same period. This gives the total weight of the sample of steam passed through the instrument; the weight of dry steam divided by this total and multiplied by 100 will give the percentage of dry steam for any given quantity of boiler steam supplied. This quality of the steam is checked for each water-consumption test. The calorimeter should be heated that the condensation may not give an undue amount of water, and the can in which the dry steam is condensed should be cooled off whenever it becomes warm.

It is sufficient for the purpose of the water-consumption test to weigh that amount of water which is condensed from the steam delivered to the engine in half an hour, taking two or three readings of quality percentage, for 10-minute intervals, by calorimeter. Two barrels into which the condenser discharges rest on platform scales and alternately receive the water which is weighed in the barrels, the tare being taken as often as a barrel is emptied. To insure accuracy the scales must be balanced before starting; the valves in the exhaust piping must also be inspected that only

the condensed steam from the engine under test may be charged and not water from other portions of the piping.

The condenser should be allowed to run several minutes before a reading is taken to ensure filling of stand pipes, etc. The weight of water delivered is taken every 10 minutes; the weights should check. The voltage and amperage is read at the same time and reduced to k. w.

From this data the steam efficiency of the set is calculated in pounds of water per k. w. hour. Total pounds of dry steam per hour and total pounds of dry steam per k. w. hour are then plotted and the curves drawn. A set of indicator cards are taken at the time of the test that the efficiency and water consumption may be calculated for the same period of the run.

XIX. Heat Rise.

The temperature rise of the set after running continuously at full rated load for 4 hours must not exceed the following:

	Method of measurement.	Maximum allowable rise in °C.
Armature	Electrical	33⅓
Commutator	Thermometer	40
Field coils	Electrical	33⅓
Shunt rheostat	Electrical	75
Series shunt	Thermometer	40

The rise of temperature to be referred to a standard room temperature of 25° C. and normal conditions of ventilation. Room temperature to be measured by a thermometer placed 3 feet from the commutator end of the generator with its bulb in line with the center of the shaft.

During the last half-hour of a heat run all apparatus is made ready and the thermometers warmed up in hot water, or better, on the cylinder of the engine; care should be taken not to warm the thermometers to a higher temperature than approximately that to be expected of the commutator or the armature core; it is best to have the readings rise to a maximum and then fall off, thus definitely determining the temperature of the required part. Five minutes before stopping several resistance readings of the shunt field are taken.

After the load has been on for 4 hours the engine is shut down.

The hot resistance of the shunt field is taken to be as that of the last readings of the heat run. The hot resistances of the armature and series field is measured by the fall of potential method, as in taking the cold resistance; all readings must be taken expeditiously as the windings will cool rapidly. The previously warmed thermometers are placed on the communicator, inside the armature core and on the pole tip. Two extra men are required for the thermometer readings in order that a running record may be kept of the thermometer readings while rising and until they begin to fall.

From the highest temperatures the heat rise of the windings is calculated by the formula on page 382 and other prescribed rises by deducting the average temperature of the air during the run; the readings of the thermometer placed on the idle machine are those to be averaged in preference to the more exposed thermometer placed in line with the shaft as per specifications. All rises are then corrected by ½ per cent for any difference between the temperature of the air and 25° C.

XX. *Heat Run at One-Third Overload.*

The generator is to be capable of satisfactory operation for a period of 2 hours when carrying one and one-third times its full load, and no part to heat to such a degree as to injure the insulation.

The foregoing conditions are tested as soon as possible after the completion of the heat run by a 2-hour run at one and one-third times the rated load.

The time consumed in taking temperatures, shutting down, starting up, etc., will usually occasion appreciable reduction in the temperature of the windings, and it is therefore customary before starting the overload heat run to run the set on full load until the rise in the series and shunt fields is again at the value found for the completion of the full-load heat run; overload must not be employed for this as the series will heat faster than the shunt and a different condition result from that obtained for the heat run.

No heat rise is specified, the test of heat rise being merely the effect on the insulation as determined in the insulation test; this fixes the heat rise to a certain extent as cotton insulation will be

injured by a temperature above 150 degrees Centigrade; the rise is, however, calculated from the original cold resistances.

The same precautions and readings are observed during this run as in the full-load heat run. Careful examination is made as to the different items of general operation of the set.

Particular items of specifications are:

1. The sets must be balanced and run true at all loads up to one-third overload.

2. The engines are to be of sufficient horsepower to drive the generator for an extended time (two hours) when the generator is carrying one-third overload.

3. Engines are to be so designed that the work done by each cylinder, as shown by indicator cards, will be as nearly equal as practicable at all conditions of load.

4. The generator is to supply the rated voltage.

5. The point of contact of the brush on the commutator shall not shift by the wearing away of the brush.

6. There shall be no detrimental sparkling when load is varied up to one and one-third times the rated load; the yellow spark is detrimental even in small amount.

The ability of the engine to keep the rated speed during the run is to be carefully noted.

Indicator cards are taken especially at the time of taking the water consumption in the last hour. Resistances of shunt and series field are recorded every half-hour and the heat rise plotted; the armature resistance and temperatures are taken at the end. The run is recorded as in the full-load heat run.

XXI. Insulation Resistance.

The specifications provide that the dielectric strength or resistance to rupture shall be determined by a continued application of an alternating E. M. F. for 1 minute; the testing voltage for sets under 16 k. w. to be 1000 volts and for sets of 16 k. w. and above to be 1500 volts, and the source of the alternating E. M. F. to be a transformer of at least 5 k. w. capacity for sets of 50 k. w. and under, and of at least 10 k. w. capacity for sets of greater output than 50 k. w.; the test for dielectric strength to be made with the completely assembled apparatus and not with its individual parts, and the voltage to be applied between the electric

circuits and surrounding conducting material; the tests to be made with a sine wave of E. M. F., or where this is not available, at a voltage giving the same striking distance between needle points in air, as a sine wave of the specified E. M. F.-as needles, new sewing needles, are to be used; during the test the apparatus being tested is shunted by a spark gap of needle points set for a voltage exceeding the required voltage of 10 per cent.

The insulation resistances are taken as soon as possible after the completion of the overload heat run when the conductors are hottest and of least insulation resistance.

In the test an alternating current transformer having a capacity of 20 kilowatts is used. The primary coils of the transformer are connected in series, secondaries in multiple, and the exact voltage is obtained by regulating the primary current, a rheostat being used for the purpose. Should a spark leap across the gap the needles are replaced before another test is made; the needle points will have burned away and increased the length of gap, thus increasing the striking voltage.

In applying this test the voltage to be used is determined as follows: Needles are first placed at a distance apart in the spark gap of 0.047 inch for 1000 volts and 0.071 inch for 1500 volts. The primary voltage is gradually increased until the secondary E. M. F. just produces an arc between the needle points. The primary voltage is now noted and is the primary voltage to be maintained during the test on the generator; it will be that which produces a secondary voltage of the same effective value as the sine wave value specified. The primary circuit is then opened, the needles are replaced by new ones, and the distance between them set for a voltage exceeding the required voltage by 10 per cent, at 0.052 inch for 1100 volts and 0.078 inch for 1650 volts.

The test is now made for the same items of the machine as in the preliminary test, the primary voltage being maintained at the value previously found; a static voltmeter across the secondary terminals gives a further check on the conditions.

There is no record made other than that the results were or were not satisfactory, if not satisfactory, the particular winding; evidently the insulation will either stand the test or it will break down.

XXII. Compounding.

The compounding is to be such that with the engine working within specified limits, field rheostat and brushes in a fixed position, and starting with normal voltage at no load or at full load, if the current be varied step by step from no load to full load or from full load to no load, and back again, the variation from normal voltage shall at no point be in excess of 2 per cent. The test is to be made when the windings are hot. The method of test is to take the generator characteristic. The combined action of the series and shunt fields to maintain a constant voltage and render the generator self-regulating is actually effected in the end by the series shunt and the whole effect is therefore referred to the efficiency of action of this shunt.

The normal speed and steam pressure is first assured and the voltage regulated to rated voltage for no load.

[NOTE 29.—This method of starting at no load may be regarded as severe though not unreasonable, and machines so tested will fall without the permissible limits. It is generally necessary to cut the field resistance all out, and then bring the voltage back to normal with a falling field: even then it will be often found necessary to take one or more full cycles of the compounding before the machine will assume a sufficiently stable condition for the actual test; for the start at full load this is not necessary and the adjustment may be made with either a rising or falling field.]

Commencing at no load, the voltage is read for increasing changes of load, usually for five equal steps of one-fifth of full load each (the steps should not be less than four), up to full load, and then down again to no load in an equal number of steps.

Full load is now put on and the voltage regulated to the rated voltage. The cycle is then repeated, but by decreasing to no load and then back up to full load. The results of the two cycles will probably differ at some points and both curves should be plotted.

At each reading the voltage and amperage of the series and shunt fields, and the speed and steam pressure are recorded.

The voltage having been adjusted at the beginning of a cycle the shunt rheostat must not be altered during the readings.

The brush rocker arm is to be set before the taking of a set of readings at the position used in the heat run. In other words, there must not be one position of the brushes for the heat rise test and another for the compounding; this meretricious artifice of using different brush positions is common enough in factory

tests and is a direct indication of insufficiency of copper in the armature winding and incorrect winding.

The changes of load must be continuous in the same direction or the results will be erroneous; *e. g.*, if changing load from 60 to 120 amperes, increase steadily to 120 amperes, but if in so doing more than 120 amperes is reached, do not shift back to 120 amperes but read the voltage for the load actually obtained; or if changing from 120 amperes to 60 amperes and the adjustment falls below 60, do not attempt to regain 60.

It is permissible that the voltmeter should become steady after each load change; if the changes up and down be made rapidly the voltage, when the load is stepped down to no load, will be greater than the original, due to hysteresis; it is sometimes separately done to test the hysteretic action of a new type of generator.

Although only the compounding between no load and full load and the reverse is specified, it is customary, inasmuch as the machines will be expected to operate in parallel in action, to continue the steps from no load up to one-third overload, the overload being one extra step. If the compounding, as per specifications, is in question the compounding up to one-third overload is tested separately.

XXIII. Engine Regulation.

a. The speed variation must not exceed 2½ per cent when load is varied between full load to 20 per cent of full load, gradually or in one step, the engine running with normal steam pressure and vacuum. A variation of not more than 3½ per cent is allowed when full load is suddenly thrown on or off the generator, with constant steam pressure either normal, 20 per cent above, or 20 per cent below normal, and exhaust either to condenser or to atmosphere. No adjustment of the governor or throttle valve during the test is to be necessary to ensure proper performance under any of the above conditions.

b. The jump in voltage must not exceed 15 per cent when full load is suddenly thrown on and off.

This test will demonstrate the ability of the engine to steadily maintain its rated speed under varying or sudden changes of load; whether the governor is in proper adjustment to control the engine speed under various loads; the strength of the various working parts to sustain abrupt changes of load in emergency, and the effect of sudden changes on the voltage.

The generator is connected up to the switchboard and load. A tachometer is applied to the end of the shaft and placed on a rest, to keep it steadily in place and as a convenience for the observer. A voltmeter is connected in at the generator terminals to test the jump in voltage. The steam pressure is carefully regulated to the normal and maintained at that reading. The rated voltage is adjusted by rheostat for no load.

The load is gradually applied by means of the load switches, and adjusted until full-rated load is indicated by the ammeter, the speed and voltage being noted for each change as the load is applied; the load is then gradually reduced to no load and the same observations taken. Full load is then switched in for the other regulation tests. The speed is not to be less than that for which the generator is rated.

The engine operating on the condenser, the circuit breaker is tripped, and the highest, lowest, and steady speed recorded, and also the highest, lowest, and the steady voltage; the circuit breaker is then closed and the same readings again taken. The cycle is then repeated. The air valve on the condenser is next opened and two similar sets of readings obtained for the operation on atmospheric exhaust. These tests have ascertained the action from full to no load on both vacuum and atmospheric exhausts for the normal steam pressure.

Twenty per cent of load is next adjusted through the circuit breaker and a similar set of 2-cycle readings is taken for full load to 20 per cent of full load for vacuum exhaust.

The steam pressure is then changed by the reducing valve to 20 per cent excess above normal pressure, and similar readings of speed and voltage are taken for full to no load and reverse, on both vacuum and atmospheric exhaust.

The steam pressure is then changed to 20 per cent less than normal pressure and a like full set of readings are taken, for full to no load and reverse on both exhausts.

Notes on Test.—If the governor shows erratic action it may be due to the sticking of some part, or to friction in bearings.

Normal steam pressure and voltage is to be assured at each set of readings.

Care is to be taken, especially in breaking the load from full to no load or to 20 per cent of full load, that the drain valves are tightly closed and the vacuum at 25 inches; the engine will evi-

dently regulate better under the conditions for atmospheric exhaust or reduced vacuum; *it is well to seal the drain valves to obviate tampering.*

In making changes from full load to 20 per cent of full load the tachometer and voltmeter are watched to detect "hunting," a bad and inadmissible fault. Hunting is that condition in which the engine does not readily assume the new steady speed but oscillates back and forth before settling to the steady speed; a good governor should bring the engine promptly to steady speed and without wavering.

In making the changes of load the working parts of the engine are to be closely watched to see that they bear the strain well.

The high, low, and steady voltage of each change indicates that the generator maintains the rated voltage and that the series shunt is adjusted to sustain that voltage within those limits which will not endanger lamps, etc., of the installation.

Racing at no load is a bad fault and is to be especially noted.

No adjustment of the throttle or governor is to be made to secure performance under any of the conditions. The engine is to be run with the throttle wide open; the governor should be capable of regulating the steam supply.

While it is not usual in the test to open the field circuit to accentuate the effect of the removal of the load, it is sometimes done for the purpose of ascertaining whether the clearance is so great as to permit the engine to race should the field circuit be broken.

XXIV. Overload.

a. The engine must be able to bear without injury the sudden throwing on or off of one and one-third times the rated full load of the generator, by making and breaking the generator's external circuit. Two readings are taken, the various working parts of the engine being closely watched, especially the governor action and voltage effect.

b. With brushes in a fixed position there is to be no flashing when one and one-third rated load is removed or applied in one stage. The overload is adjusted for normal steam pressure, speed and voltage. The circuit breaker is tripped and the effect on the working parts and any flashing noted. Flashing occurs mostly

in those improperly designed machines in which the neutral point shifts through a wide range. It is more convenient and to the saving of time to make these tests by breaking the load suddenly at the end of the overload heat run.

XXV. Magnetization or Saturation Curve.

This test is made on one generator of a delivery of two or more to complete record data; it will develop the sufficiency of the field-core areas and is useful in tracing defects in compounding.

The field of the machine is separately excited by the storage batteries; the armature is driven at constant speed, and a voltmeter is connected to the brushes for the voltage generated; before starting the residual magnetism should be "kicked out" of the fields. At the start the increase in voltage is great for small increments of current; the latter is raised in very small steps, until the "knee" of the curve is reached; after this has been passed the rate of change in the voltage begins to decrease as the field cores reach saturation and consequently the current must be increased for a given increase in the voltage. After the current in the field has reached its greatest permissible value, it is reduced in steps and a similar series of voltage readings taken which, when plotted, will not coincide with those given by the increasing current but will lie above them. Any changes in speed are to be allowed for.

Care is taken to always change the current in the same direction; that is, while readings are taken for the first portion of the curve—with increasing field current—never to decrease the current until the peak of the curve is reached, and *vice versa* on the coming-down curve.

If, on examination of the curve, the rated voltage of the dynamo intersects well up on the "knee" the machine is in a stable magnetic condition; if the voltage intersects on the straight part of the curve any small derangement of the shunt-field current will cause an abnormal change in the magnetism and consequently in the terminal voltage.

As an incident, if the curve be compared with text-book saturation curves (such as Ewing's) for different metals, a fair inference may be drawn as to the material of which the field cores are composed.

XXVI. Field Compounding, or Armature Characteristic.

This test is made for the completion of record data of a new type, size, or style of generator and upon one of a lot; it will show the relative amount of magnetization produced by the series-field ampere-turns and, in the case of a new machine, when the number of turns on the shunt field is known, gives a direct determination of the turns required for the series field.

In this test the shunt field of the machine must be separately excited and the series turns left out altogether. The armature current is varied in steps from 0 to 150 per cent of the rated load and back again, the volts of each step being brought to the normal by varying the shunt-field current. Speed is kept as nearly constant as possible; readings of field amperes and load are taken at each step. The curve is then plotted.

The field current must always be varied in one direction as in the magnetization curve, changing it when the maximum point of the curve is reached.

The curve is plotted for field currents as ordinates and armature currents as abscissæ; the terminal voltage is maintained constant. It affords a means of determining the extra voltage due to the series field, and thus a check on a machine which does not compound well.

XXVII. Parallel Operation.

Generators of the same type and manufacture are to be capable of operation in parallel, the division of the load to be within 20 per cent throughout the range.

If several machines of the same kind are under inspection, it is necessary to test capability of operation in parallel. This is done at various loads, the loads being thrown on and off in steps, carefully noting whether the division of the load between the machines is within the specified limit of 20 per cent throughout the entire range up to full load.

XXVIII. Efficiencies.

Only the electrical efficiency is provided for in the specifications. The set efficiency is quite as important as it includes the engine performance as well, and is usually included in the test record.

a. Electrical Efficiency.—The minimum allowable efficiencies of the generators are as follows:

K. W.	Loads.			
	$1\frac{1}{3}$ Per cent.	1 Per cent.	$\frac{3}{4}$ Per cent.	$\frac{1}{2}$ Per cent.
2.5	78	78	76	73
5	80	80	78	75
8	84	84	83	80
16	87	87	86	84
24	88	88	87	85
32	88	88	87	85
50	89	89	88	86
100	90	90	89	87

The electrical efficiency, the ratio of the generator output to the total watts generated in the dynamo, affords a practical criterion of the performance of the dynamo as compared with known percentage losses of high-class generators. At any load the output in watts, plus the core loss which is constant at all loads, plus the various C^2R losses, gives the input, from which the per cent efficiency is readily calculable.

The C^2R (or heat) losses are those in the armature winding, shunt winding, series winding, shunt rheostat, brushes, leads, brush contact, and series shunt.

The C^2R losses having been determined, it remains to derive the core and friction losses. The motor method is employed as it gives results which are sufficient practically, though lack of balance of the cranks is not separable by this method.

The connecting rods are cast loose from the crank pins that the crank shaft may revolve freely and a motor is belted to the fly wheel to drive the armature, the whole adjusted to permit no slip of the belt. When the motor is supplied with current and is driving the generator armature at its rated speed, part of the energy is dissipated as C^2R loss in the motor armature and field, etc., and the remainder is expended in turning the two armatures against frictional and other opposing forces; the losses due to these are equal to $CE - C^2R$. In which $C =$ current supplied to the motor armature; $E =$ the E. M. F. at the motor terminals, $R =$ motor armature resistance taken hot.

The result will contain the frictional losses in both machines in addition to the core losses, due to the magnetization of the generator; these frictional losses must be accurately determined and subtracted from the value obtained by the above formula for

each reading. The input into the motor when running at that number of revolutions per minute which will be necessary to drive the generator armature at its proper speed is very carefully determined.

When the motor has run until thoroughly warmed up, the belt is thrown off and the hot resistance of the motor armature is then taken; the test proper now begins. The motor is again belted to the fly wheel and the generator armature and crank shaft are driven at rated speed with the brushes off the commutator. The increased input consumed by the motor is now due to windage and main bearing friction of the generating set; this amount can be divided between the generator and engine proportionately to the number of bearings of each; the windage is not separated in the allotment. The brushes are next lowered on the commutator at proper running tension and the speed adjusted; the increase in input into the motor is chargeable to brush friction.

Current is next passed through the generator field, started at some low value and increased in steps up to the greatest permissible value and back again; at each step the speed is adjusted and the motor input noted; the increase of input is due to increase of core losses. Several sets of readings are taken which should check closely and from them a curve can be plotted and the required core loss obtained.

The following practical considerations are of service when this test is performed. The motor field is to be maintained constant under all conditions and as strong as is compatible with safety; the motor field loss does not then enter into the calculations; there is freedom from sparking; the armature current is small; the errors of adjustment and observation are to some extent lessened, and the motor core losses will be constant. It is preferable to use a motor with copper brushes; with carbon brushes the C^2R loss due to brush contact is widely variable.

b. Overall Efficiency.—The overall efficiency, also known as the commercial, net, or set efficiency, is the ratio of the indicated horsepower of the engine to the electrical horsepower output. It is more convenient to express the quantities in kilowatts and obtain the ratio in this way. The indicated horsepower is derived from the indicator cards taken for different loads, using a planimeter, the amperes and volts being noted for the time of taking the cards.

XXIX. Range of the Circuit Breaker.

When a circuit breaker is supplied with the generator it is usually dismounted and tested in the test room. It is then set for its different currents as shown on the scale, is read, and the current slowly raised to the value for which the circuit breaker should operate and the amperes noted for which it actually operates for that scale reading. The circuit breaker must not be so connected as to open the field circuit.

XXX. Range of Field Rheostat.

The total range of adjustment by the shunt-field rheostat is to be from 10 per cent above to 20 per cent below the rated voltage of the generator; the variation to be not more than one-half volt per step at both full load and half load.

The steam pressure being normal and the voltage at the rated value for no load, all resistance is cut out of the rheostat and the resulting voltage noted; all resistance is then put in and the voltage again noted.

Full load is next switched in, the voltage adjusted and the variation of voltage from block to block noted; the same operations are made at half load.

The intention is to avoid a rheostat of coarse graduations which would affect the lamp life. A convenient time for makng the test is at the time of taking the compounding.

XXXI. Interchangeability among the different sets and their spare parts, of the same size and make, as furnished in any one contract is required; this to be demonstrated as part of the final test for acceptance.

The engine is taken apart and examined for wear or scoring in bearing surfaces, particularly within the cylinder and valve chests and reassembled with the spare parts, and parts of other similar engines under test to ensure that they fit properly and are interchangeable. This is often in error and would occasion much inconvenience on board ship when one set is to be rehabilitated from another, or parts are to be replaced by spares from store.

The spare armatures are placed in position in the fields and are given the same tests as the armatures which are in place when the set is received.

Motors.

The items of inspection of a motor depend largely upon the specifications in the particular contract and these will vary for a given output; with the nature of the duty to which the motor is to be applied; the location of the motor as regards exposure to heat, dust, and moisture; whether the motor duty is to be continuous or intermittent; the nicety and range of regulation, etc.

The specifications may be separated into two divisions for inspection:

I. The mechanical and electrical features of the motor as a means of converting the electrical input at the brushes into mechanical work given out at the shaft, the machine being considered as a dynamo converting in an opposite sense.

II. The performance on a desired duty, or an examination into the efficiency of the application and control of the output at the pulley for the work to be performed.

Under I, therefore, the motor is tested as to its good mechanical construction and its efficiency of conversion of energy, and, under II, as to the prescribed performance on applied use.

The mechanical construction is exactly covered in specifications and test in this respect is made by examination of the separate items in the machine itself and from drawings.

Electrical and Operative Features.

The tests are to determine balance, heating, insulation, sparking, efficiency, etc., and, incidently, the operation of any speed-regulating apparatus.

Balance.—I. The armature is to run true; II. The armature to be balanced mechanically and electrically.

The motor is first run as a generator before preparing for the heat run, and the electrical balance of the armature circuits is measured as for a dynamo.

Heating.—This is determined by a heat run of the motor at the rated output (full load), at the rated input (volts and amperes per name plate).

The permissible heat rise and duration of run varies in specifications for the various types of motors.

Heat Run.—For the heat run of motors (except ventilating motors) the motor is belted to a generator which thus independently supplies the load. The generator may be of a larger

size and of different voltage from that of the motor but should be preferably of the same size and voltage; a duplicate pair of motors is usually available, one to act as the motor under test, the other being driven as a generator by the motor. The generator is connected up to a load consisting of German silver rheostats as in testing dynamos; lamp banks or water boxes can be used, but cannot be as conveniently regulated.

The cold resistance of the motor armature and field are first measured and the motor is then connected to a supply circuit whose voltage must be higher than that of the rated voltage of the motor.

The starting box, controller, or controlling panel which is to be used with the motor is connected in the supply line and used during the heat run; it is first to be assured that the connections will cut in the field before current has access to the armature and will cut out the field only when the armature current has ceased.

Before starting, rheostats are connected in the armature and field circuits and short-circuited by switches. These rheostats can be quickly introduced by switches and can be quickly introduced after the heat run and the readings made for the drop with different current values without changing the source. The armature is measured with the field circuit open by disconnecting at one binding post of the field ammeter and opening the short-circuiting switch; the field is measured by opening the armature circuit in a similar way.

The motor is next started and brought and kept to its rated input of volts and amperes by regulating the load on the generator; the rated input, as developed in the factory test, is taken as giving the rated output; if the input is not known the motor losses are first determined and are added to the rated output to determine the necessary watts of input at the rated voltage of the machine.

Thermometers are placed on the motor frame; on the bearings; on the armature of a similar machine nearby if possible; in the air in front and back of the machine 3 feet from, and on a line with, the shaft; on the overload and no-voltage spools of the panel, and within, and near the center of, the controller casing.

The heat run is then started and continued for the prescribed number of hours. Readings are recorded every half-hour, if the run is greater than one hour, or every 15 minutes if for one hour

only. Portable instruments are employed and are carefully calibrated before starting the run. The voltmeters are kept out of circuit by cut-out switches, and the ammeters by short-circuiting switches, except at the time a reading is taken, to prevent injury to the instruments from heating and from sudden fluctuations or overload, and in the case of ammeters to keep the instruments from changing calibration.

Items of observation and report during the run are:

I. Motors are to be designed to operate on the voltage of the prescribed installation (now 125 volts).

II. All connecting pieces and other current-carrying parts to be so proportioned that no undue heating will occur when they are worked under the severest possible conditions.

III. All the field poles to be equally energized (electrical balance).

IV. The motor to be at least capable of developing the rated (specified) horsepower output for the total time of the continuous heat run.

V. The shaft and bearings of **turret motors** to be provided with thrust collars which will limit the end play to the smallest practicable, and which will stand a continuous end thrust at least twice in amount that developed by the gearing to be used and the maximum output of the motor without the collars heating or cutting.

VI. There is to be no sparking when running at the rated speed and output, nor must there be any injurious sparking on reversal. Some sparking usually occurs; if it is not a red or yellow spark, and retains the blue color, it is not detrimental.

At the expiration of the heat run the hot resistances are measured, the thermometer temperatures read, and the heat rises calculated as for a dynamo. The curve of rise for the field is plotted during the run. The various readings and measurements are similar to those for generators.

Insulation Resistance.—Two insulation tests are usually made as in the case of dynamo: the ohmic test in which the electrical circuits, including the control panel, are to show one megohm to ground and between circuits with a direct current at 500 volts; and the dielectric or rupture test in which the insulation is to stand the application of an alternating current potential of 1500

volts for one minute. These tests are made in the same manner as described for dynamos.

Efficiency.—This is specified for one-quarter, one-half, three-quarters, and full load, and is also tested for 25 per cent overload.

The specifications prescribes "the highest commercial efficiency for the size and speed" and may be considered to vary at full-load ranges from about 73 per cent for motors of 1 horsepower to 85 per cent for motors of 10 horsepower, and up to 90 per cent for larger sizes. These estimates will be found to be well below those actually obtained for well-constructed commercial machines.

Probably the best method of determining the efficiency of motors is that in commercial use and known as "Stray Power" or "Loss" method, *i. e.,* determination of the various losses. The method is sufficiently correct for practical purposes, and avoids the difficulties attending methods necessitating the application of full load to the machine, and the measurement of the mechanical output. The Hopkinson method for full-load efficiency has objections and is probably less accurate than the "Stray Power" method.

The only data required, other than that already obtained, are core loss, windage, brush and bearing friction, and the total armature-circuit resistance, which includes the armature winding, brush contact, brushes, and leads to the terminals of the machine.

This data is obtained immediately after the temperatures are taken at the end of the heat run as follows:

(*a*) The total armature-circuit resistance is measured by the fall of potential method between the terminals of the machine. Current and voltage readings are taken in the same manner as in determining the resistance for the heating tests, except that the armature is turned to several positions, about five in all, with three values of current at each. From these 15 readings a good average value is obtained for calculating the C^2R loss in the armature circuit.

(*b*) The core loss (hysteresis and eddy currents), windage, brush and bearing friction are obtained in one observation.

The belt is removed, the motor started up, and the field current adjusted to the last value observed in the heat run (by the rheostats provided in the field and armature circuits). The armature will then be running under the same conditions as when carrying

full load, hot. Readings are then taken of armature volts and amperes. For the amperage a low-reading ammeter is used (corresponding to the small current) but of sufficient range to give a sizeable deflection. The product of these two readings, less the C^2R loss in the armature circuit, gives the required losses.

The other losses are obtained by calculation. The C^2R loss in the field is calculated from the hot resistance measured for the temperature rise at the end of the heat run and the current as shown in last reading in the heat run; this loss remains constant for all loads. The C^2R loss in the armature circuit is obtained from the measured resistance and the armature current for the particular load.

The sum of all these losses deducted from the input give the output. The efficiency is computed as the ratio of the output to the input, both in the same notation.

The method neglects:

(*a*) Additional friction loss in bearings due to increased pressure caused by the pull of the belt; this should not properly be charged to the motor as it does not appear in direct-connected machines.

(*b*) Iron losses in pole tips when the machine is loaded. This is small in modern machines using laminated pole pieces.

(*c*) Iron losses in armature core due to the constantly reversing current in armature winding.

(*d*) Changes in core loss, due to reduction of the flux by the back-ampere turns when the motor is loaded.

The foregoing losses are so small that they may be considered negligible in practice.

Speed Regulation.—For constant-speed motors the variation in speed from no load to full load is not to be more than 9 per cent in motors of less than 5 horsepower, and not more than 6 per cent in motors of 5 horsepower and above. This is determined by direct observation by a tachometer, noting the speed at no load, one-quarter load, one-half load, three-quarters load, and at full load. The machine should be hot when the observations are taken.

Ventilating Fan Motors.—While motors of this type are given a heat run test at the factory when separate from the fan, the motor and fan assembled together is the usual method of delivery for test.

Strictly speaking, the heating determination requires two separate tests for the full time of heat run; one, with full voltage on the field (lowest speed) for the actual field heating on this duty; the second, with a full rated current on the armature and weakened field (highest speed) to determine the highest heat rise of the armature.

The test is ordinarily made as to heating, etc., when driving on open exhaust on the "hold up" in lieu of free exhaust. The hold up is accomplished by attaching to the fan outlet (or nozzle) a duct whose length is 48 inches, whose larger diameter in inches is that suitable to fit the fan outlet and whose smaller diameter is determined (by a factor for the particular type of fan) from the "hold-up area" in square inches; this area is equal to $\frac{DW}{3}$ in which D is the diameter of the fan wheel and W is the width of the wheel, both in inches; the factors for various sizes are as follows:

TABLE FOR TESTS OF EFFICIENCY REQUIRED FOR ELECTRIC FANS WITH CAST IRON SHELLS AS PER U. S. STANDARD SPECIFICATIONS.

Curved Float Wheel.			Full Outlet.				$\frac{DW}{3}$ Outlet.				Weight.
No.	$\frac{DW}{3}$	R.P.M.	Vol.	H.P.	K.W.	Press.	Vol.	H.P.	K.W.	Press.	
	Sq. in.		*Cu. ft.*			*Oz.*	*Cu. ft.*			*Oz.*	*Lbs.*
		1285	296	.072	.053	0.25	197	.055	.035	0.50	
1	9.32	1820	420	.205	.153	0.50	280	.155	.115	1.00	
		2230	512	.381	.284	0.75	342	.285	.212	1.50	
		1140	429	.105	.784	0.25	285	.079	.059	0.50	
2	13.5	1620	608	.300	.224	0.50	404	.225	.168	1.00	215
		1980	740	.555	.414	0.75	494	.418	.312	1.50	
		950	604	.149	.111	0.25	403	.112	.087	0.50	
3	19.0	1350	867	.420	.312	0.50	578	.315	.235	1.00	337
		1650	1040	.780	.572	0.75	695	.590	.440	1.50	
		800	833	.204	.152	0.25	555	.153	.114	0.50	
4	26.3	1130	1178	.579	.432	0.50	785	.435	.322	1.00	513
		1390	1450	1.080	.806	0.75	967	.815	.607	1.50	
		700	1052	.260	.194	0.25	702	.195	.145	0.50	
5	33.2	994	1480	.740	.552	0.50	987	.555	.413	1.00	
		1220	1815	1.370	1.022	0.75	1270	1.025	.726	1.50	
		595	1846	.460	.343	0.25	1230	.350	.261	0.50	
6	58.7	842	2620	1.300	.970	0.50	1765	.980	.73	1.00	
		1030	3235	2.400	1.79	0.75	2150	1.800	1.340	1.50	
		520	2660	.650	.485	0.25	1770	.490	.365	0.50	
7	83.3	736	3720	1.830	1.36	0.50	2488	1.380	1.028	1.00	1050
		902	4680	3.410	2.54	0.75	3040	2.560	1.910	1.50	
		452	3605	.890	.664	0.25	2400	.670	.506	0.50	
8	113.7	640	5100	2.510	1.87	0.50	3400	1.88	1.400	1.00	
		784	6250	4.640	3.46	0.75	4165	3.500	2.610	1.50	

Operation on Required Drive.

The ability of the motor to operate on the use to which it is to be applied is tested, as far as practicable, by handling weights at the works of the contractor under the action of its own controlling apparatus, rheostats, and connections; but its final test is specified to be made after installation on board ship in the position and location in which it is finally to be employed, and the details depend on the items of specifications for the particular case. The following are given as examples:

Turret-Turning Motors.—When the installation of turning gear is completed on board ship the completed turret is to be turned from extreme train on one side of the vessel to extreme train on other side, and a stop made as each abeam position is reached (the turret being started again immediately after being stopped), the speeds and accelerations being the maximum, the control of the turret to be maintained throughout the full arc of fire as follows:

Turrets are to be able to be turned at a maximum rate of 100 degrees of arc per minute, and at a minimum rate of about ¼ degree per minute.

The turret is to be able to be accelerated at such rate that it can be started from rest and brought to within 10 per cent of its full speed of 100 degrees per minute in 10 seconds of time, and while turning at its full speed to be able to be stopped in 5 seconds of time.

This cycle of operations is to be continued for a continuous period of one hour, without the temperature rises as follows: each motor to be tested by running it for a continuous period of one hour at rated horsepower and voltage without increasing the temperature of the series field more than 70° C., the commutator 65° C., the armature and any other part 60° C., above the surrounding air. The shunt windings to be able to carry full current continuously for 2 hours without increasing their temperature more than 50° C. above the surrounding air. If the system of control is such that maximum heating occurs at a speed other than the maximum, a similar test to be made at speed corresponding to the maximum heating effect.

The turret will also be operated on each controller notch a sufficient number of times to demonstrate satisfactory working.

When actually turning a turret on board ship the two motors

must equalize their load within 10 per cent of full-rated load when running in series or parallel (according to system used) at all speeds and directions.

Ammunition-Hoist Motors.—One ammunition-hoist equipment complete with controller, rheostats, circuit breakers, etc., is considered as typical of a set of similar equipments and is subjected to the following tests:

A weight of 4000 pounds is hoisted and lowered continuously during one hour; starting with its weight supported by the lower stop, hoisted 50 feet, then lowered till its entire weight is supported by the lower stop. The total number of feet traveled by the load during the hour is not to be less than 12,000, and the elapsed time of hoisting or lowering from start to stop not to exceed 10 seconds.

At the completion of the test the temperature above that of the surrounding air shall not exceed the following: Series-field windings, 70° C., measured electrically; shunt-field windings, 50° C., measured electrically; commutator, 65° C., measured by thermometer; armature or any other part of the motor except bearings, 60° C., measured by thermometer; bearings, 40° C., measured by thermometer.

The motors are to be capable of carrying an overload of 50 per cent for 5 minutes without appreciable sparking or overheating, and a momentary overload of 100 per cent without injury.

The motors are to be fitted with such braking device that the load will not fall when the controlling lever is in any position, no matter what variation of current or voltage may occur; this braking device is to be capable of holding a load of 4000 pounds.

The following is the method pursued in testing desk and bracket fans:

Test of a New Type of Fan Submitted for Approval as to Type, Construction, and Performance.

The fan, which is rated at 1/6 or 1/12 horsepower, and of either the bracket or desk types, is first taken apart and a rigid inspection made.

The electrical test necessitates the bringing out of a special circuit from the junction of the rheostat in the base and the field coil in order to obtain the drop across the field which will be

taken between the circuits just described and the brush terminal at which the field and armature join.

The cold resistances of the field coil and armature are first taken; that of the latter being taken by holding two sets of 2-pointed terminals, one for current and one for drop, across commutator bars diametrically opposite, taking the reading of the current and drop; this operation is repeated for several sets of commutator segments, care being taken to select bars diametrically opposite, and taking comparative readings on the same bars. The average of these readings is taken as the cold resistance.

The fan is then started up and the cold resistance of the field coils immediately taken. The line voltage, current, and drop across the field is taken every 15 minutes until the fan temperature has reached a maximum when the fan is stopped and the armature resistance (hot) is taken in the same manner as the cold resistance was taken. From the hot and cold resistances heat rises are calculated as for dynamo windings.

After this is finished the fan is carefully re-assembled (or another of the same kind is taken if several of the same types are submitted for the heat run) and is then subjected to a life test. This test shows the ability of the fan to operate over long periods with little or no adjustment and consists of a 500-hour continuous run, during which readings are made of volts, amperes, speed, air velocity, temperature of room and of motor frame. Volts and amperes input are ascertained in the usual way.

The speed readings present the difficulty that no speed counter or tachometer can be applied to the shaft as these cause a pressure on the shaft and cause the fan to absorb more power or will cause a marked change in speed; the stroboscope is therefore employed to check the speed. The stroboscope consists of a metal disc in which four openings, about the size and shape of fan blades are cut; this disc is rotated by a motor, a tachometer being directly connected to its motor shaft. If now the disc be rotated with constantly increasing speed and the revolving fan be observed through the openings of the disc, the fan blades will seem to run or move more slowly as the speed of the disc approaches that of the fan, until, when the fan and disc are revolving at the same speed the fan will appear to stand still; the tachometer connected to the stroboscope shaft is now read and gives the number of revolutions per minute of the fan.

The air velocity of the fan is read by means of an anemometer placed one foot in front of the plane of revolution and moved in a line at right angles to the extended line of the shaft until the highest reading is obtained; this will determine the maximum velocity of air discharged at full speed which is specified at 1200 feet per minute for a 1/12-horsepower fan and 1500 feet per minute for a 1/6-horsepower.

A close following of specifications should permit no adjustments to brushes, lubricating devices, or bearing during this run; but should a fan stop due to some minor or easily remedied defect, such as a poor brush, this would be remedied (noting the circumstances) and the run finished.

Upon the competition of the life test an insulation test is made on the assembled fan which must show at least one megohm measured with 500 volts applied one minute, after which the fan is taken apart and examined for wear of shaft and bearings, condition of commutator, armature, field brushes, etc.

Test of a Fan of Approved Type.

Each fan is subjected to a 4-hour full-speed run, during which readings are taken at the beginning and at 1-hour intervals for determining heating, watts input, speed by stroboscope, and velocity (maximum) of air discharge. At the end of the 4-hour run an insulation test is made. All of these observations are taken by the same methods as pursued in the life tests of a fan submitted for approval.

The air velocity formula used is:

$$V = 940\ (459.4 + t)\ \frac{h}{B}.$$

t = temperature of fan air in degrees Fahrenheit.
h = inches of water in pressure gage.
b = barometer reading in inches of mercury.
V = velocity in feet per minute.

This formula corrects to a standard room temperature of 50° Fahrenheit, and for a barometer reading of 29.92 inches and uses a coefficient of discharge for a conical mouth piece of 0.98.

CHAPTER XI.

AUXILIARY APPARATUS AND INSTRUMENTS USED WITH GENERATING SETS AND MOTORS OR FOR TESTS.

Reducing Valve.

There are three types of reducer in use, but none are advised to be installed in other than a horizontal position as the valves are likely to chatter and the steam pressure to oscillate.

Foster, New Class W Valve.—The construction of sizes of 2½ inches and over, is shown in cross-section in Fig. 211.

A.—Inlet. *B.*—Outlet, when used as a straightway valve. *C.*—Outlet, when used as an angle valve. *D.*—Diaphragm chamber. *E.*—Steam-port, connecting valve chamber with diaphragm chamber. *F.*—Diaphragm. *G.*—Valve-stem. *H.*—Double-seated valve-clapper. *K.*—Nut for regulating discharge pressure. (Turn to the right to increase, and to the left to diminish pressure.) *M.*—Port screw for closing or partly closing off steam from diaphragm chamber.

A slot in the head of the port-screw indicates the direction of port in the sizes of 2 inches and under. The regulator being in a vertical position, the port-screw is open when the slot is vertical. Port-screws having no slot in the head (used on valves 2½ inches and over) are closed by turning the screw to the right as far as it will go.

The regulator is provided with a balanced valve, constructed to insure a tight seating under all conditions of temperature and pressure. The body of the valve is so made that the inner and outer castings are connected with expansion-resisting webs, which carry off the heat by radiation equally on all sides, and thus prevent distortion of the seats out of true. Elongation of the neck between the two clappers is compensated for by making the upper seat almost flat, and the lower seat nearly straight (15 degrees off the vertical line). By this means the upper seat is brought to its bearing by force of the delivery pressure acting on the diaphragm, while the lower seat finds its bearing by diametrical expansion.

The power to resist the closing of the valve is secured by interposing toggle-levers between the diaphragm and the spring. The increasing power of the spring as it is compressed is compensated for by the increasing power of the toggle-levers as they come into line.

Before attaching the valves blow out the pipes thoroughly; after the valve is attached blow steam through it in order to carry away lead, cuttings, or other foreign substances that may have lodged on the valve seats. Do not use red or white lead to make pipe joints; use oil, or Dixon's Pipe-Joint Grease.

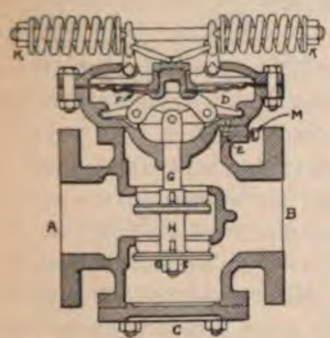


FIG. 211.—Foster new class W reducing valve.

FIG. 212.—Curtis reducing valve.

A strainer should be attached directly to the inlet of the regulator and should be thoroughly cleaned beforehand.

The steam must pass through the regulator in the direction indicated by the arrow cast on the side of the body. The outlet may be either at *B* or *C*.

When making connections to the regulator, the pipes should be cut and the fittings made up in such a way as to avoid any strain on the pipe or regulator. When possible, use an adjustable hanger on each side of the regulator to relieve the stress.

After all connections are made and while steam is passing through the valve, regulate the delivery pressure by turning the

spring nut *K* to the right to increase, and to the left to diminish, the discharge pressure or volume.

If there should be violent pulsation of the diaphragm when delivering steam to an engine turn the screw *M* slowly to the right until only a slight movement is perceptible—exactly as a steam-gauge is throttled to prevent the hand from vibrating; attention to this important matter will prolong the life of the diaphragms. If the valve "chatters" turn the screw slowly to the right until the noise ceases.

When delivering steam to an engine, or a pump, locate the regulator as far from the steam-chest, or engine, as the piping will admit. As a rule, the cubical contents of the pipe between the regulator and the steam-chest should be as great as that of the steam cylinder; this provides a cushion which prevents a constant movement and wear of the valve.

Curtis Pressure Regulator.—The construction is shown in cross-section in Fig. 212.

It is to be located in an upright position in a horizontal pipe and in some place where it can be easily got at. The steam should flow in the direction of the arrow on the side.

When ready to start the regulator first turn back the handle on top, until all pressure is removed from the spring, then turn on the high pressure. If in order the regulator will open for a few seconds (until the chamber over the piston fills) and then close, shutting off all pressure beyond it. Next open wide the globe valve, between the regulator and the high pressure, then turn down on the handle of the regulator until the valve opens, and continue turning down slowly until the desired pressure is reached. A slight turn of the handle either way will alter the pressure and when once set a uniform pressure will be maintained. If the regulator should fail to close when the handle is turned back and taken out, it will be on account of dirt. If the pipes are new or recently put together, blow steam through for some hours before opening the regulator; this will blow out the dirt and red lead and dry up the oil on the inside of the pipes.

To open the regulator for examination, first turn off the handle on top and take out the spring under it; remove the cap, taking care to slide it off sideways, with the hand under the diaphragm to keep it in place. Unscrew the cap inside by means of the square top, then remove the spring and valve under it. If the

valve sticks it can be pushed up by the stem projecting through the bottom.

See that the set, valve, piston, and stem are clean and free from all dirt and chips, or iron or brass, and the hole in the piston (about the size of a pin) clear. Slip off the spring ring carefully, and if the valve does not drop freely into its seat (when perfectly clean) take it out, reverse it, and try the piston bottom side up; also try the stem by reversing the piston and pushing the stem up from the bottom. Wipe the stem perfectly clean; if it is cut polish it with fine emery paper and wash out all of the emery. If in order the valve should drop freely into its place on its seat like a check valve and be perfectly free when everything is hot.

Before replacing the inside cap, see that the secondary valve (in it) is free from dirt and perfectly tight. Screw the inside cap to its seat and close up the regulator by putting on the outside cap (containing the diaphragm and follower) and screwing it firmly to its seat, thus making a steam-tight joint without the use of lead. There should be no dirt on the top of the regulator where the diaphragm makes its seat and the diaphragm should be clean; such a joint is not likely to leak. The diaphragm goes in with the bead up. Next open the stop valve wide and turn down on the handle of the regulator to start.

The working of the valve can be seen by taking off the acorn at the bottom; little steam will escape.

The Leslie Pressure Regulator.—The type (Fig. 213) proves very satisfactory in service and is especially efficient when frequent changes of steam pressure are required as in test work. All Leslie high-pressure regulators, Class E, are made of U. S. Government composition.

The main valve *D* is held in position (when not in operation) by the spring *E*. It is convexed to insure greatest possible strength and is so guided at all times, increasing its life and efficiency. It is actuated by the spring *E* by the initial pressure, being opened by the initial pressure on top of the piston *F*, and closed by the spring *E* and the initial pressure under the main valve *D*.

The piston *F* is actuated by the initial pressure and the spring *E*; the initial pressure is admitted on top of piston *F*, from the port *S*, through a controlling valve and port and is counteracted by the initial pressure and spring *E* against the bottom

of the main valve *D*, the stem of which is fitted into the piston *F*; both main valve *D* and piston *F* operate simultaneously and are controlled by the controlling valve. The piston *F* is fitted with spring rings and is protected from dirt from the boiler by having no flow of steam through the cylinder. The dirt will follow the current and pass out with the delivery flow.

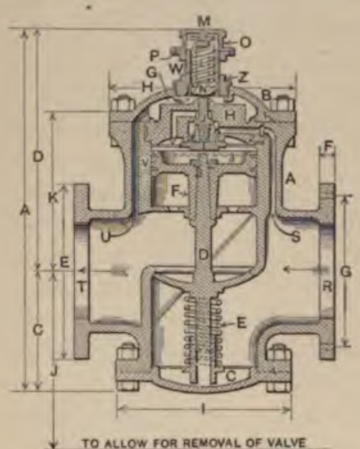


FIG. 213.—Leslie reducing valve.

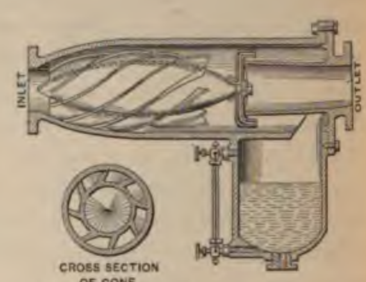


FIG. 214.—DeReycke separator.

The controlling valve is held in position (when not in operation) by a spring. It is opened by screwing down the adjusting cap *O* on the adjusting spring which forces the diaphragm *G* down on the stem of the controlling valve and opens the latter, allowing the initial pressure to pass through from the port *S* into the port *V*, to the top of the piston *F*; the reduced pressure enters the port *U* on the delivery side and acts on the diaphragm *G*, balancing the action of the adjusting spring; as the pressure tends to decrease under the diaphragm *G*, the controlling valve and the main valve *D* open proportionately more, until equilibrium exists between the pressure that the adjusting spring is set for, and the reduced pressure under the diaphragm *G*. The size of the diaphragm *G* is the same in all regulators from ½ to 1½ inches. The adjusting spring will give a range of pressure from zero to 85 per cent of the initial pressure up to 250 pounds per square inch.

The adjusting caps *O* are made to be adjusted with a spanner wrench; they are held in position by the lock nut *P* and can be

sitively secured in position by a lock so that they cannot be npered with.

The regulator must be placed in a vertical position, so that am will pass through in the direction indicated by the arrow t on the side of the body. The regulator should preferably placed as near the boiler as possible. *A stop valve must be iced on the inlet pipe.*

Graphite or oil is to be used for making up pipe joints, never iite or red lead, cement, or any kind of gum.

To set the regulator: first unscrew the adjusting cap *O* by ning to the left until the tension is entirely off the adjusting ing (a small spanner wrench is furnished to fit the adjust- cap *O*) then open the stop valve or drain pipe on the delivery e to allow condensation to pass off freely; then open the stop lve on the inlet side very slowly until it has been opened full; n screw down the adjusting cap *O* very slowly by turning it the right, a fraction of a turn at a time (to give ample time get rid of condensation and to thoroughly heat up), until the sired pressure on the delivery side is obtained, when the lock- t *P* should be set up tight against adjusting cap *O* to hold the ter securely where set. It is important when setting to see at sufficient flow of steam at the initial pressure is obtained.

Where extensive piping is used, or in places where considerable ater from condensation is likely to flow back to the regulator, e water should be trapped off before it reaches the regulators; e regulator will make a noise while the water is passing through id may also act as a water ram on the piston until it has forced e main valve open sufficiently to allow the pressure on the de- very side to increase to almost the initial pressure; this is apt force sediment or other foreign substances into the working arts.

If a regulator should become sluggish and not recover quickly, pecially on new ships, the trouble may be due to gum, lead, or her cement from pipe joints in the working parts which has ked on, particularly so on the seat of either the controlling or e main valve.

Working parts and inside the cylinder should be cleaned with rosene and a cotton rag. If lead, pitch, or gum should get into e piston ring or grooves, the piston should be placed in a pan bucket of kerosene and the rings turned around in the grooves

until the obstruction has been entirely dissolved; then stand it on edge for a few minutes to allow the dissolved matter to drain out, after which wipe off dirt and oil; when kerosene is used for cleaning, parts must be wiped off dry before being assembled; both valves and seats should be examined carefully to see that the valves seat properly all around.

Separator.—Two types are usually installed, the De Reycke and the Stratton.

De Reycke Separator.—The construction is shown in cross-section in Fig. 214.

The separator consists of a shell or casing in which there is firmly secured a stationary double-ended cone. On this cone are cast a number of knife-edged wings, extending spirally along its exterior, the annular space between the cone and the shell of the separator being equal at its smallest cross-section to that of

FIG. 215.—Stratton separator.

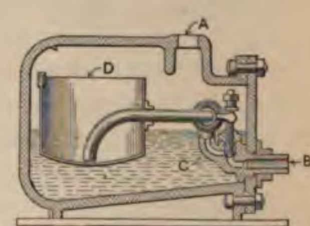


FIG. 216.—Dinkel steam trap.

the steam pipe; from thence it is greatly enlarged. At the outlet end of the shell there is an annular space, formed by an inwardly extending outlet pipe. On entering the separator the steam is spread and thrown outward by the cone and given a centrifugal motion by the spiral wings. These wings are constructed with curved surfaces tangential to the cone; this materially aids in producing an outward flow of the water. Steam on entering the separator is immediately expanded from a solid volume (due to the size of the pipe) into an annular space of equal volume, whereby its particles are removed farther from the center, and receive a greater amount of centrifugal force. Under these conditions the entrained water meets curved angular wings along

which it flows outward to the shell of the separator, and is collected in a well; here it is entirely isolated from the flow of the dry steam, which passes off through the outlet.

Stratton Separator.—The separator (Fig. 215) is based on the principle that, if a rotative motion is imparted to the steam, all the liquid particles it may contain, being heavier than the steam, acquire centrifugal force and are projected to the outside of the current.

The separator consists of a vertical pear-shaped (or cylindrical) casing with an internal central pipe extending from the top downward for about half the height of the apparatus leaving an annular space between the two.

A nozzle for the admission of the steam is on one side, the outlet being on the opposite side or on top as may be most convenient in making the connections. The lower part of the apparatus is enlarged to form a receiver of considerable capacity, thus

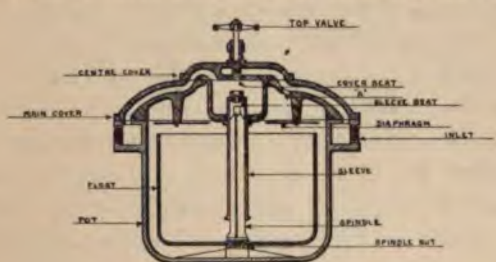


FIG. 217.— Nason steam trap.

providing for a sudden influx of water from the boiler. An opening is tapped at the bottom for a drain pipe to the trap whose valve should always be left open. A glass water gauge shows the level of the water.

The current of steam on entering is deflected by a curved partition and thrown tangentially to the annular space at the side near the top of the apparatus. It is thus whirled around with all the velocity of influx, producing the centrifugal action which throws the particles of water against the outer cylinder which has wings or plates projecting inward and standing at an acute angle to the course of the current, thus breaking up the whirling motion, and allowing the water to settle quietly to the bottom, whence it passes off through the drain pipe.

Pressure Gauges.—The type of steam and vacuum gauge is

the ordinary adaption of the Bourdon principle, known as the Ashcroft gauge; the dial face is 5½-inch diameter.

Steam Trap.—There are two varieties in use, the Dinkel and the Nason.

Dinkel Steam Trap.—The construction is shown in cross-section in Fig. 216.

A is the inlet; *B*, the outlet; *C*, the valve; and *D*, the copper bucket.

This trap consists of an open float bucket, lever attachment, and trap valve, all contained in a casting. The valve is held closed by the pressure in the chamber and opened by the increased power from the lever attachment. The trap shown is for a steam pressure of about 160 pounds. All the working parts are inside of the trap-chamber and are connected to the cover; in cleaning or repairing the working parts are removed with the cover.

The operation of the trap is as follows: As the chamber fills with water the bucket floats and rises until it strikes against the top of the chamber and can go no further, the water continues to rise until it flows over and fills the bucket, causing it to sink to the bottom of the chamber; the weight of the bucket is such, that by its operation the valve is opened, the water in the chamber above the top of the bucket and the water in the bucket, is then discharged, the bucket rises until it floats again and the discharge valve is closed. The valve is so arranged that a body of water is always left above the valve seat after each discharge, consequently steam cannot escape as it cannot be forced through the water.

The amount of water delivered at each discharge depends on the size of the trap-chamber. The time required for each discharge depends on the pressure in the trap-chamber.

To ascertain whether the trap is working open the air-cock; if water escapes, it shows that something prevents the trap from delivering, but if steam escapes it shows that the chamber has not yet filled sufficiently to cause the bucket to drop to the bottom of the chamber and open the delivery valve. As soon as steam comes from the air-cock close the cock and keep it closed.

Nason Steam Trap.—The construction is shown in cross-section in Fig. 217.

A cast-iron reservoir, or pot, is closed with a cover provided

with two cored passages and contains a float which is fitted with a spindle for its guide. A housing or sleeve is screwed centrally into the under side of the cover and within it the float spindle fits snugly, permitting, however, a short vertical motion. The top of the float spindle is ground flat and its upward movement is arrested by coming in contact with a bronze plug having a central opening, the two surfaces thus constituting a discharge valve for the trap.

One of the cored passages in the cover, is for the discharge of water from the trap after passing through the main valve, and the other serves as a by-pass, to permit any large volume of air or water to be blown through, when starting, without going through the cylinder and discharge valve. A valve (not shown) located externally in the cover gives entire control of this action.

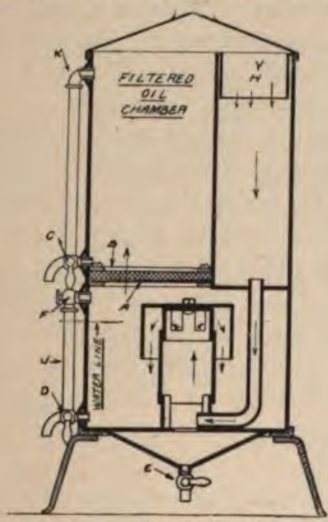


FIG. 218.—Hall Fitter.

Care should be taken that the trap is in all cases placed below the surface from which water of condensation flows. The discharge enters at the point marked "Inlet," and passing through the hole "A" into the body of the trap, a diaphragm above the float diverts the water of condensation into the pot, where, gradually rising, it first raises the float, thereby closing the discharge valve, and then, after reaching the top of the float, the water flows into it. When the float has nearly filled, its weight overcomes the tendency of the discharge valve to remain closed,

being held there by steam pressure, and the float drops to the bottom, opening the valve. Acting on the surface of the water the steam pressure immediately drives it up through the sleeve, discharge valve, and thence by way of the cored passage to the outlet. When the float has nearly emptied it becomes so light that it is again raised by the water about it, closing the valve, and the operation is repeated. This action is purposely intermittent, necessitating that the valve shall be either wide open or completely closed; the life of the valve is thus prolonged, and it will remain tight for a longer period.

The trap has no motive power within itself, and is not a return trap; water must run into it by gravitation and the discharge should ordinarily be into the open air or a hot-well.

Waste Oil Purifier.—*Hall Waste Oil Purifier and Refilter.*—The apparatus (Fig. 218) consists of a tank of galvanized iron divided into four compartments by galvanized-iron partitions; an oil receiver, the washing compartment, a false bottom, and a chamber for the filtered and cleaned oil.

The oil to be cleaned is poured into the strainer box *H*, which has a bottom of fine brass mesh, straining the oil in its passage to the receiver. From the receiver the oil passes by a pipe to a cylindrical receiver located in the large water compartment in the base, which compartment is filled with water to the level shown, and the oil is washed in its passage through the water in passing through *A* into the filtered oil chamber above *B*. The sediment settles into the false bottom and is drawn off at *E*.

To the top of the distributing chamber is strapped an annular cap which spreads the oil and water coming from *H* and thus acts as a separator.

At *A* and *B* is an assemblage of filter pads held between two strainer plates and a large mesh and secured against a flange of the bottom by follower rings, stud bolts, and nuts. A glass gauge shows the height of clean oil and is fitted with a stop-cock *C* by which the filtered oil can be drawn off for use. A glass gauge *J* shows the height of the water level; the level can be maintained by drawing off the excess water through the stop-cock at the bottom of the gauge.

When starting, clean the apparatus thoroughly, especially the compartment for filtered oil. Place the filter pads and screw the follower ring tight; the pads are a species of Canton flannel with

a nap on both sides, two are generally used but if oil can be passed in sufficiently large quantities it is better to use three or four pads. See that the bottom cocks of the gauge glasses and the emptying cock of the false bottom are closed to air. Pour water (preferably warm water) into the strainer box *H* until the water lever is up to the level mark. Next pour the dirty oil into *H*, two quarts at a time, until it appears in the bottom of the clean oil compartment, after that keep *H* full.

The pads should be cleaned by washing with soap at least once a month; if the filtered oil appears dirty put in new pads and clean the clean-oil chamber. If the oil to be cleaned is very dirty place a piece of canvas in the bottom of the strainer box *H*.

The water should be kept to the marked level.

The gauge glass cocks are three-way and can be closed tight should the glass be broken.

Switchboard.—There is so much variation in makes and types of switchboard in use, varying in construction with the number and sizes of generating sets installed, that no general rule can govern; but distinction is made between what is known as the *Standard Switchboard,* for three or more generating sets of 50 k. w. or 100 k. w. capacity—or a mixture of them—and the *Special Switchboard* for two generating sets of less than 50 k. w. capacity; it being generally contemplated that the latter type is not required to distribute to power circuits, or that the small amount of power to be used does not require any especial consideration and can be supplied by switches similar to those for the lighting distribution.

The Standard Switchboard.—The available space in a dynamo-room does not admit of that most convenient arrangement of having the distribution board in extension to the connections to the generating sets, thus having but one general board, and utilization of space requires the division of the switchboard entire into two sections: the *generator*, or *dynamo-room, board,* located in the dynamo-room, and the *distribution board,* located in a compartment near or contiguous to the dynamo-room; a similar arrangement being made for both the forward and after dynamo-rooms.

[NOTE 30.—A more recent arrangement is to have but one dynamo-room in the vessel and assign two distribution-rooms, one at either end of the ammunition passage and amidships: the forward of these contains the

dynamo-room switchboard as well, from which direct connection will be made to a distribution board in the forward distribution-room for all electrical energy required in the forward half of the vessel, and to the after distribution-room for all of the remainder.]

The Dynamo-Room Switchboard.—The front view of a board for four 100 k. w. dynamos is shown in Fig. 219, and the diagram of connections (panels reversed as compared with Fig. 219) in Fig. 220.

There are three panels (Fig. 219). Each panel is of 1½-inch slate, the face being enameled; the material is a good insulator and is preferable from the diagonal nature of its cleavage when fractured, thus forming a better temporary restraint from those short circuits which would be occasioned by the contact of the loosened through-bolts than is assured by a break in marble; enamel prevents the absorption of oil and water and gives a finish.

The middle panel accomplishes all necessary functions in relation to the actual machine connections and contains, from top to bottom (see also Fig. 220):

1. Four circuit breakers of 1200-ampere capacity which form the connection for the positive lead of each of the four dynamos separately.

2. Four ammeters, of the shunt type, one in each positive lead of the four dynamos.

3. Four voltmeters, each connected from the positive lead of the particular dynamo with which it is associated to the common negative bus bar.

4. Four hand wheels adjusting the individual shunt rheostat of each of the four dynamos. The hand wheel is furnished with a pointer in front of the board showing the stops or blocks passed over from "High," when the rheostat connects in least resistance in series with the shunt field and the dynamo is developing highest practicable terminal voltage, to "Low," when all practicable resistance due to the rheostat is in series with the shunt field and the terminal voltage is lowest. The hand wheels are mounted on a shaft which turns the lever of the shunt rheostat; the last named is usually mounted well to the rear of the back of the switchboard, preferably higher up; in this case a sprocket chain gear is assembled with the shaft and rheostat lever.

FIG. 219.—Dynamo-room board (Connecticut).

5. A set of single-throw knife switches of 1200-ampere capacity mounted in four rows of two switches each, the switches of succeeding rows being staggered for convenience of operation. The four switches of the two upper rows, one each for each dynamo of the dynamo-room, are connected through the board to

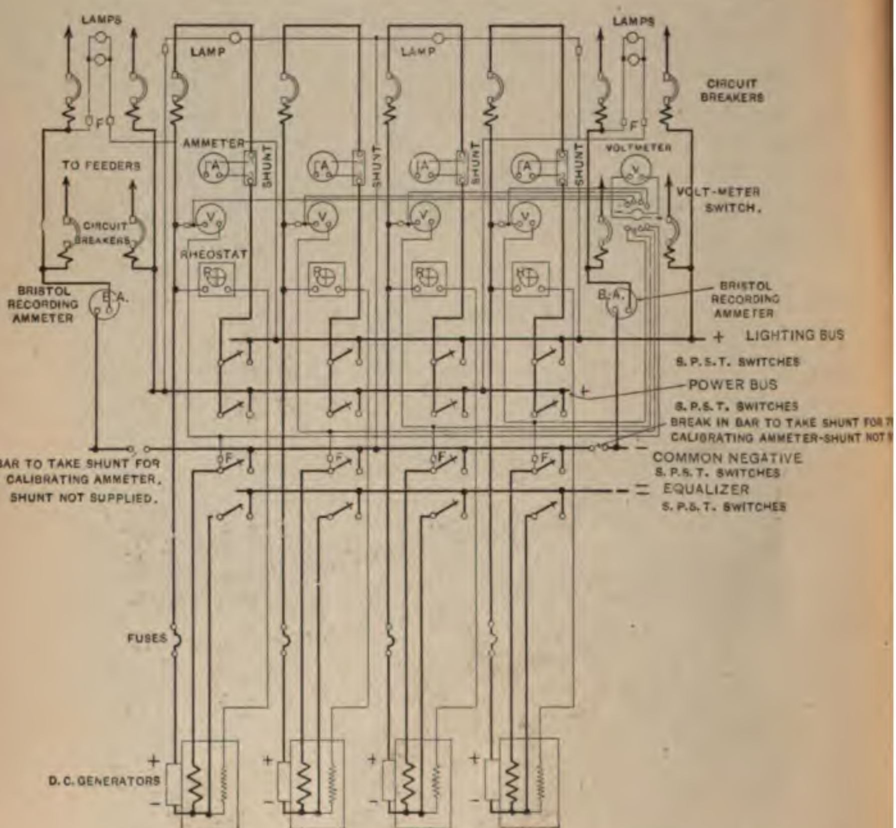


FIG. 220.—Connections dynamo-room board (Connecticut.)

a heavy copper slab running across the back of the panel set off from it by studs, and forming the positive bus bar for all energy to be taken off for distribution under the classification of "lighting"; in order to distinguish these lighting switches *their wooden handles are painted red.*

The four switches of the next two rows are for switching off energy to the positive bus bar of the "power" division, and are

similarly connected through the board to a heavy bus bar set off the back of the panel by studs and farther off than the bus bar for lighting. The switch handles for power *are painted white.*

Below the above-mentioned switches are two other rows on a separate panel; more often the upper two rows of these sets are included in the larger panel. The upper two rows connect the negative lead of each machine to the single common negative bus bar on the panel and form the negative connections for both power and lighting; the switches connect through the switchboard to an extra heavy bus bar that runs outside of the other bus bars on the back of the board and must be separated from them at least 1¼ inches for 125 volts. The switch handles for the *common negative are painted blue.*

The bottom row of four switches connect the four equalizer leads of the four dynamos to a common equalizer bus bar when paralleling. These switch handles are usually black, but being smaller, the switch being designed for but 750 amperes, are not readily confused with those for the common negative.

The panel shown on the right (Fig. 219) contains two sets of single-pole circuit breakers, the outer breakers being connected to the positive power bus bar and the inner to the common negative bus bar; the upper pair of the two sets is for connection to the distribution-room of the other dynamo-room (forward as shown) and the lowest pair to the distribution-room nearest the dynamo-room in which the generator board is installed.

The panel shown on the left accomplishes for lighting what that on the right does for power, the capacity of the circuit breakers being 800 to 1000 amperes and 2000 to 6000 amperes, respectively. This panel also contains a voltmeter which can be connected successively in parallel, through the switch shown lower down, with each of the other four voltmeters and the latter be thus calibrated and checked.

Below the power and lighting panels are installed Bristol Recording Ammeters, of 5000-ampere and 800-ampere capacity; they serve to record those variations of load during 24 hours, which ordinary readings at the end of each hour as recorded by log rarely show, and which are useful in tracing heavy loads or overloads as causes of faults or repair.

The Distribution Board.—A design of distribution board common to battleships is shown in Fig. 221. A diagram of the

connections is shown in Fig. 222 and in which the arrangement is reversed from left to right as compared with Fig. 221.

There are three panels on which are mounted the connections to the various circuits to which the energy from the dynamo-room bus bars is to be distributed; these three panels are designated: lighting panel, left; power panel, center; and turret panel, right.

FIG. 221.—Distribution-board (Connecticut).

The lighting panel contains, from top to bottom:

1. Three circuit breakers of 100-ampere capacity, the left and right of which are in the positive lead to each of two 30-inch search-lights; the center breaker is of 200-ampere capacity and is in the positive lead of each of two 60-inch search-lights.

2. A set of six instruments; the upper left hand is the voltmeter for the search-light circuits, the separate circuits for the three search-light lines being connected at will to this voltmeter by the voltmeter switch near the hand wheels (below); the upper center instrument is an 800-ampere ammeter which shows the total load in amperes which is in use on the lighting circuits; the upper right hand instrument is a voltmeter which shows the actual

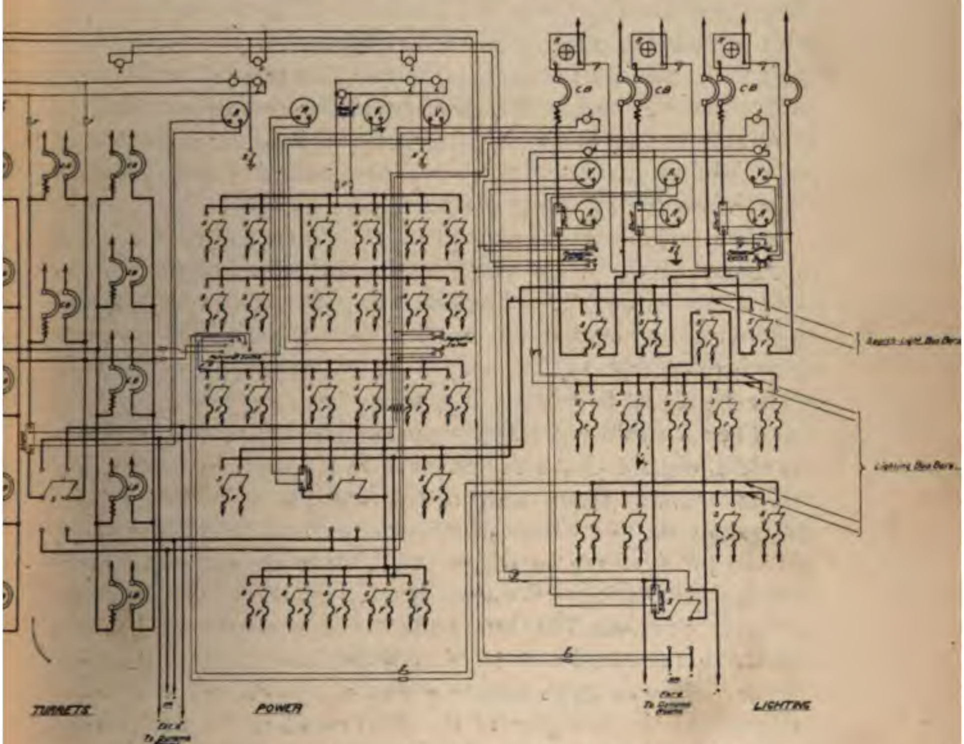


FIG. 222.—Connections of distribution-board (Connecticut).

voltage across the bus bars of the lighting panel; the three lower instruments are ammeters; the left and right are 100-ampere and indicate the current for the 30-inch search-light circuits, the center instrument is 300-ampere and indicates the current for the 60-inch search-light circuit, a switch near the hand wheels indicates whether for the forward or after 60-inch projector.

3. Three hand wheels (the adjacent switches have been mentioned) which control the adjustable search-light resistances on

the three circuits, the rheostats being located near the distribution board and connection made to the hand wheel shafts as in the case of the shunt rheostats of the dynamo-room board; the dead resistance of the search-lights is located elsewhere at any desirable location; ordinarily, but not conveniently, this is the dynamo-room.

4. Three rows of double-pole switches; the upper left and right being for the connection to the positive and negative search-light bus bars for the 30-inch search-light branches and the middle two for the 60-inch projector circuits. The two lower rows are the positive and negative connections to two sets of positive and negative bus bars for the feeders of the distribution panels or large lighting circuits of the vessel or distribution panels in the ship. These are generally of 100-ampere capacity.

5. The large double-pole, double-throw switch to form the connection of the whole panel, except for search-lights, to the positive bus bar on the lighting lead from each of the two dynamo-rooms and the negative bus bar fed from the common negative of each dynamo-room.

The center or power panel contains from top to bottom:

1. Four instruments. The right-hand instrument is a 130-0-130 scale Weston Ground Detector with a switch for connecting in the positive or negative leg of the circuit to be tested, and the various circuits of all three panels can be connected to it through switches provided on the power panel. The right center instrument is a 2000-ampere Weston ammeter for the total current on all turret circuits. The left center is a 2000-ampere Weston ammeter for the total current of all power circuits other than for turrets. The left-hand instrument is a 150-volt Weston voltmeter across the bus bars of the power and turret circuit connections.

2. Three lines of double-pole, single-throw, 100-ampere switches for the various power circuits of the vessel.

3. Two 500-ampere, double-pole, single-throw switches for feeding boat-crane and air-compressor motors. A double-pole, throw-over laminated transfer switch for connections to bus bars for search-lights; these circuits derive their energy from the power panel and not from the lighting panel.

4. A row of five 200-ampere, double-pole, single-throw switches for miscellaneous power circuits.

The turret panel consists of a set of double-pole circuit breakers on the various divisions of energy for power use within the turrets only. There is also mounted on this panel a 2000-ampere, double-pole, throw-over laminated transfer switch which controls the whole load of the panel. The outside studs of this switch connect to two sets of bus bars that are led in connection with those on the power panel, one set being fed from the forward dynamo-room and the other from the after dynamo-room.

The following is a list of the circuit breakers and their uses:

Two type C, form P, 800-ampere circuit breakers for 12-inch turret ordnance power; two type C, form P, 300-ampere circuit breakers for 12-inch turret-turning motor-generator sets; four type C, form P, 300-ampere circuit breakers for 8-inch ordnance power; four type C, form P, 200-ampere circuit breakers for 8-inch turret-turning motor-generator.

The panels of the dynamo-room and distribution boards are mounted by bolting them against angle-iron framing and are set with the lower edge about 12 inches above the deck if at all practicable. The front of the panels are illuminated by shaded lamps placed at the top, usually two in the center panel and one in each side panel; the connections on the back of the board are illuminated by a lamp in the center of the top of each panel.

In making terminal connection to the board for the ends of the feeders, the ends are soldered into connectors similar to that shown at *A* (Fig. 90). Some connections between boards require two or more wires in order that the largest number of circular mils in one wire will not be greater than 1,000,000 circular mils; in that case a grouping of two or more connectors into one are required; *e. g.*, the connections from the dynamo-room switchboard forward to the distribution board aft in a large battleship requires four one-million circular-mil wires for each leg, positive and negative.

All appliances on the switchboard are marked with name plates; each voltmeter and ammeter has stamped on it the number of the generator with which it is in circuit or a name plate corresponding to its search-light or motor circuit.

Distribution Panels.—In order to minimize the number of switches on a distribution board, to decrease the number of wiring appliances in the circuit and to afford a convenient means of controlling lighting mains or mains from which are branched

several small motors, it is customary to install distribution panels at convenient places in the ship. They are slate panels provided with knife switches only, the panel being protected by a perforated ventilating cover that can be locked.

Circuit Breakers.—In general, circuit breakers are used in place of fuses on all circuits of large current capacity which are subject to overload. In effect they are an automatic, circuit-opening switch, with an adjustable range of operation. Their chief point of advantage, perhaps, in addition to preventing excess of current, is in enabling the circuit to be closed with but a small loss of time as compared with that required to replace a fuse; this is of especial value in circuits for motors, such as for turret-turning, ammunition hoists, gun-elevating, and ramming.

The general features of construction comprise:

1. The main switch contacts.

2. A set of auxiliary contacts which make and break the circuit before and after, respectively, the closing and breaking of the main contacts.

3. A locking device holding the main and auxiliary contacts in closed position.

4. A tripping device, usually actuated by a solenoid, to open the locking device.

5. An adjustment for the position of the iron armature in relation to the solenoid.

6. A scale to indicate the range of adjustment that may be obtained.

7. A spring device to rapidly open the main and auxiliary contacts when the locking device is released.

General Electric Company's Types.—This company manufactures different forms of magnetic blow-out (type M) automatic circuit breakers for different classes of service, mainly single-pole. These different forms have some radically different features to adapt them to the special classes of service for which they are designed. All may, however, be used on switchboards or on any direct-current circuit, and with reasonable care and attention will operate under the most severe conditions. The feature of the magnetic blow-out is in the setting up of magnetic lines at right angles to the arc, which increases the actual length of the arc by deflection until it is ruptured by the failure of the voltage to maintain it. The tripping point is adjustable to any desired

current, from 50 per cent below to 50 per cent above rated full-load capacity, by adjusting the calibrating spring of the tripping armature. Destructive arcing is prevented by the use of supplementary contacts placed in a strong magnetic field and arranged to break the circuit a moment after the main contact. The transfer of the arc from the main to the supplementary contacts, and the immediate extinguishing action of the magnet, has made possible the construction of effective circuit breakers for 10,000 amperes capacity. The main contact, which is built up of leaf springs, bears upon the main contact blocks when the circuit breaker is closed. The coil of the blow-out magnet and the

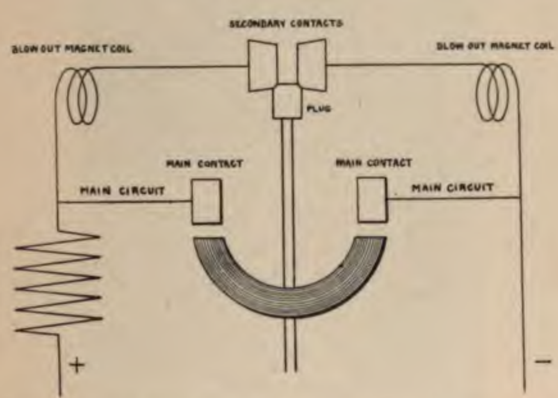


FIG. 223.—Elementary diagram of General Electric Company's type M circuit breaker.

secondary or plug contacts are in multiple with the main contact. Owing to the comparatively high resistance of the secondary contacts practically no current passes through them until the main contacts open; then the whole current passes through the magnet coils and the strong magnetic field extinguishes the arc as soon as it is formed on the plug contact. The plug is not withdrawn until after the leaf contacts have left the contact blocks.

The general diagram of connections of type M circuit breakers is shown in Fig. 223.

The strongest and most rugged of the type M breakers is the **form K-3** (Fig. 224), which differs from the form K in the main brush, the manner of tripping, the arrangement of the

secondary contacts, and in the dash pot. The tripping coil, with the connecting studs and nuts, used on the type M, form K breaker is not used on the type M, form K-3 circuit breaker. The necessary power for tripping the latter is obtained from a magnet which is made in the form of a strap encircling one of the main studs at the rear of the panel. Studs are carried through the panel to support the armature and form the necessary magnetic circuit; the armature spring and scale plate are, therefore, on the front of the panel and in an accessible position. The general

Fig. 224.—Type M, form K-3 circuit breaker, General Electric Company.

method of operation is shown in Fig. 223. The secondary contacts are held in place by a hinged clamp, and are so arranged as to be easily removed upon taking off the pole piece and can be quickly examined or repaired. The dash pot has an air cushion which permits the use of a strong spring to increase the speed of opening of the main brush and to lessen the shock. All sizes of type M, form K circuit breakers are designed for back connections; up to and including 800 to 1200 amperes capacity they can also be furnished for front connection. When the circuit breaker is open, it can be locked open by removing a handle; as the circuit breaker cannot be closed without the handle, removal

of the handle prevents accident or unauthorized closing of the circuit.

The **type M, form L** (Fig. 225) circuit breaker is for use on small power plants where the conditions are not severe, and where a breaker cheaper than the form K, type M is desired; in large plants where severe conditions have to be met its use is not recommended, and the type M, form K breaker should be used in preference. The principle of operation of the form L is the same as that of the form K, but the moving parts are somewhat lighter and differ slightly in general form. The form L circuit breaker

FIG. 225.—Type M, form L, circuit breaker. General Electric Company.

is made in two capacities: 100 to 500 amperes, for front and back connection, and 200 to 800 amperes for back connection only.

As in the case of the form K, the main contacts of the form L circuit breakers are laminated and connected in multiple with the secondary plug contact, upon which the arc is broken. The automatic locking handle is supplied on this circuit breaker.

The **type M, form Q** circuit breakers (Fig. 226), which are made for capacities up to 175 amperes only, are especially designed for protecting power circuits and stationary motors. In general appearance, it is somewhat similar to the form L, but it has no secondary contact, though it has arcing tips to protect the main contacts. The current is broken in a segmental contact

similar to the contacts used in railway controllers. This form of contact has been found sufficient for the maximum capacity of this circuit breaker. There is but one coil for both the tripping magnet and the magnetic blow-out. The magnetic circuit is so arranged that the arc is ruptured in the field.

The automatic circuit breakers, **type C, form D** (Fig. 221, top of switchboard) are furnished in both the single and double-pole constructions; the single-pole is used in the generator circuit of some of the switchboards and the double-pole in motor and search-light circuits. The auxiliary contacts consist of carbon blocks fixed solidly to the main contacts. The moving auxiliary

FIG. 226.—Type M, form Q, circuit breaker. General Electric Company.

contacts consist, on either pole, of two curved strips with reinforced ends which make contact in each side of the carbon blocks. The tripping device has an external armature, held away from the core by the spring in tension which is located in the vertical line of the apparatus; an adjusting screw varies the tension of this spring over the range of a scale mounted back of it, thus giving various settings for the current at which the circuit will be opened.

Ward-Leonard Types.—The circuit breaker shown in Fig. 227 is designated as the DH type, double pole, quadruple-break, back-connection.

The details of the construction are as follows:

The main switch contacts on either pole consist of two composition castings, the rear part extending, in a threaded nut, through the slate, and beyond, for the attachment of the nuts which secure to the cable terminal.

The front extension is in rectangular form and milled with grooves, the number depending on the amount of the contact area required. Connection between these front extensions is made by flat copper strips on edge in pairs, each pair being sprung apart by a slitted brass-spring which insures that the entire side of each of the copper strips makes good contact; these strips are as-

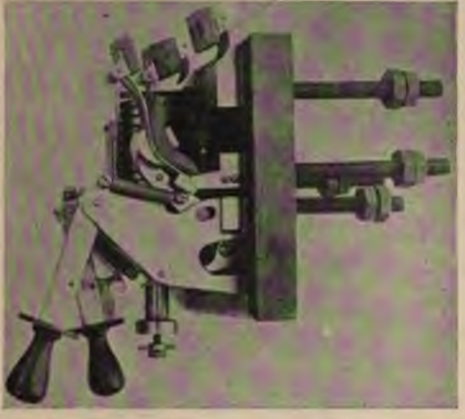


FIG. 227.—Ward Leonard DH circuit breaker.

sembled together in a casting which, with the handle, constitutes the switch lever for one side of the circuit.

The auxiliary contacts consist of carbon blocks attached by flat springs to the main contacts. These are connected together, when the switch is closed, by a long carbon block mounted on the side of the casting which holds the flat copper strips.

The locking device consists of a hooked catch pivoted between lugs on the lower side of the main contact. A coiled steel spring tends to keep the catch normally in the closed position; extending from the inner side of the catches are fingers which disengage the catch when operated on by the tripping device.

The tripping device consists of an armature core in an iron-clad frame surrounding a solenoid which is in one side of the circuit.

The operating device is a coiled steel spring mounted in a cylindrical chamber on an extension below the lugs between which the switch lever is pivoted. A shouldered steel stud is pressed upwardly against a boss on the switch lever and tends to hold the switch open; a similar one works directly against the copper strips between the main contacts.

The special feature of this circuit breaker is that it opens both poles of the circuit and it is not necessary to have a special switch in series with it, a feature which is of advantage in the limita-

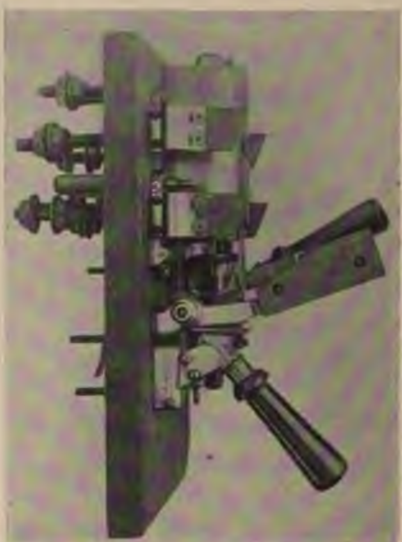


FIG. 228.—Cutter (I. T. E.) circuit breaker.

tions of space on Naval switchboards. By closing first the le[illegible] on one side of the circuit and then the lever on the other side[illegible] an excess of current flows, the tripping device will be actua[illegible] and the lever which was first closed will fly open.

Cutter Company's Types.—The Cutter circuit breakers [illegible] designated as the "Dublarm" laminated-type, I. T. E. (inve[illegible] time element), overload circuit breaker, shown in Fig. 228.

The main details of the construction are as follows:

The main switchboard contacts, in either pole, consist of t[illegible] rectangular blocks on the face of the board from which, extend[illegible]

ough the slate, are threaded studs with nuts by which the le terminals are secured.

'he surfaces of the contacts are plane; connection is made be-en them by a number of thin copper strips assembled together bent in a curve, the ends being bevelled off so that, as they inge on the main switch contacts, they will spread out and h will make a firm elastic contact of high efficiency. The tion along the surfaces of the block insures brightness of tacts.

'he auxiliary contacts are double: the first one is made by a per finger extending from the side of the lower main switch tacts; and the second by two carbon blocks, one being at-ied to a saddle above the upper main contact, and the other g attached to a saddle and spring and connected to and ring with the lever to which the bent copper strips are at-ied. The moving carbon is electrically connected with the er main contact by an insulated strip, secured on top of the copper strips and insulated from them by mica; a block of per at its lower end makes contact during its arc of travel with first auxiliary contact already described. In some sizes there heavier, bent copper finger overlaying those assembled to-ner for the main contacts which acts as another auxiliary tact.

'he locking and tripping devices have the same general features he Ward-Leonard circuit breaker already described.

'he opening device consists of phosphor-bronze springs which l to close a linked joint of the toggle.

Rheostats.

'he term rheostat is applied to any type of resistance that is rted in an electrical circuit for the purpose of cutting down voltage, the loss in potential, or drop in volts, being numeric-equal to the value of the resistance in ohms multiplied by current in amperes passing at the instant. If a lever or er is combined, by which the resistance in circuit can be varied, rheostat is designated an adjustable rheostat, of which the nary or typical form is a simple helix whose turns are ilated from each other by the insulation of the wire or by ng laid in grooves on a cylinder of hard rubber or other in-ating material.

Much ingenuity has been used in designing rheostats to accomplish the purpose of good range and variation in resistance, by paralleling or placing in series, or a combination of both, at the same time providing for good radiation of heat to keep the resistance material to its normal resistance value; the potential reduction in a rheostat being dissipated as heat, the energy so dissipated may be considerable as cited in the case of searchlight circuits.

Line Rheostat.—This type is usually a variable resistance, or dead resistance in a line for bringing down the voltage value from that of the line to that required for the particular application. A particular case is the Carpenter rheostat used with the

FIG. 229.—Pressed ribbon (PR) rheostat.

photometer; this type has a number of wires embedded in powdered enamel, the enamel being baked to a solid mass; good radiation is effected by casting ribs on the disc.

Shunt Rheostat.—This rheostat is colloquially termed the **box,** to distinguish it from starting boxes. Formerly this type was constructed by winding two sets of wire on slate bases, the lever connecting by brushes on the bared surface of the wire; latterly the various forms are more like starting rheostats and the resistances are made of coiled German silver wire or simply ribbon on insulators.

Starting Rheostat.—This type has been spoken of in connection with motor control. The type is colloquially known as a **starting box.**

Instances of rheostats commonly met with on board ship in connection with power circuits are the following:

The Pressed Ribbon (PR) Rheostat.—The PR type of rheostat is shown in Fig. 229. It consists of two cast-iron end frames held in position by four rods. To each end frame is cemented a fire brick having six slots. These fire bricks support six panels of filling, differing somewhat in the various rheostats, but consisting essentially of malleable-iron top and bottom strips provided with binding posts, between which are stretched back and forth several layers of German silver ribbon, the different layers being insulated from each other by asbestos. In addition to the German silver resistance many panels have iron radiating pieces inserted between the various layers to assist in dissipating the heat. The rheostats are generally so mounted that the panels lie in vertical planes, allowing the air to circulate freely between them and carry off the heat; to prevent the absorption of moisture the panels are dipped in japan.

The binding posts consist of lugs, provided with set screws, cast on the top and bottom plates. A binding post is provided at both ends of each panel for convenience in making connections to the controller. The panels are connected together by short copper strips fastened by screws to the top and bottom plates. The connections are such that the six panels of the rheostat are in series with each other, but in some cases longer strips are used and the panels are connected either two or three in multiple. These rheostats are designated by a serial number, such as 218; if the panels of the rheostat are connected two in multiple the series number is followed by the letter A, as 218-A, and if connected three in multiple it is known as 218-B.

The panels are insulated from the iron frames by the fire bricks; to give more insulation, insulating bushings are provided for the bolt holes in the feet of the rheostat frame so that each rheostat frame is insulated from the ship; should the connections in any way make contact with the rheostat frame the whole system would be grounded.

The panels have terminals at each end for connection of circuits and also flat plates which connect the panels together. The

points at which each circuit should be attached to the panel are determined by trial and are shown in the diagram of the rheostat connection furnished with the controller. The number designating the filling of the rheostat is stamped on the end of the frame; if it is necessary to install a spare one an exact duplicate should be employed.

The Packed Card Rheostat.—This type of rheostat is for circuits of moderate capacity and is so proportioned as to give a uniform variation in resistance. The type derives its name from the method of construction.

A tube of asbestos (Fig. 230) on a steel mandrel, is wound with German silver wire or ribbon; it is taken from the mandrel

Wound tube and pressed cards.

Showing iron plates between car

FIG. 230.—Packed card (PC) rheostat.

and pressed in the V-shape section shown; this construction constitutes the card and is the unit resistance used in making up the rheostat. The cards are assembled side by side with asbestos between successive cards, the number of cards determining the amount of resistance. To increase the radiation surface, iron plates, somewhat wider than the cards, are inserted at intervals between the cards and project beyond the resistance section; the

cards and iron plates are then clamped by end plates and bolts. The use of cards enables a large amount of resistance to be placed in a comparatively small space, while the shape into which they are bent insures their maintaining a fixed position.

Voltmeters and Ammeters.

The Weston types are preferred and constitute the general supply.

The general principle is derived from that of the D'Arsonval galvanometer. A coil of wire (Fig. 231) is wound on a rectangular bobbin of thin sheet copper or aluminum and mounted in delicate jewel bearings, on brass mountings secured to the poles of a permanent steel magnet, to whose poles are secured pole

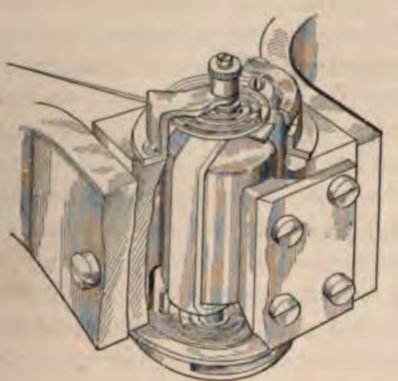


FIG. 231.—Coil and poles of Weston instruments.

pieces of soft iron which carry the magnetic lines to more closely embrace the coil. Within the coil is a hollow soft iron cylinder, whose office is to concentrate the magnetic field through the coil. Motion of the coil is controlled by a coiled spring at the top and bottom; when a current passes through the coil the bobbin swings to bring the lines of force due to the current parallel with those of the permanent magnet; this motion is resisted by the spring, hence the spring is the controlling force, and the instrument is independent of the earth's force. The bobbin also exerts a restraining force, due to the induction of an inverse current in the closed circuit of the bobbin metal while the coil is moving; this

induction has the important effect of damping the oscillations of the needle and rendering the instrument very dead-beat.

The needle is of aluminum, the vane set vertically to give as narrow and fine an indication as possible, and a mirror arc is placed below the needle to eliminate errors of parallax. The coil terminals connect to the spring, the other end of the spring being connected to the instrument resistance. As the angle of deflection is nearly proportional to the current strength the divisions of the scale are uniform. It is evident that for a deflection of a given number of scale divisions, for scales of the same maximum, the current strength in the coil will depend upon the potential at the coil terminals and will be the same whether the instrument be a voltmeter or an ammeter; it only requires about 0.015 ampere for the full deflection to the scale maximum.

The essential difference in construction between the voltmeter and ammeter is the method of impressing the appropriate potential at the coil terminals for the difference in method of instrument use.

For the voltmeter, which is to be connected directly from the positive to the negative side of a line and thereby derive the full potential of that line, it is necessary that a sufficient resistance be inserted in series with the windings of the movable coil that the full potential of the line may be reduced to that voltage which will cause the coil to swing the needle to the appropriate scale division; the amount of resistance in the coil spring, and instrument resistance taken in series, differs with the full scale maximum, but approximates 100 ohms per scale division; this gives about 15,000 ohms as the resistance of a 0 to 150-scale voltmeter and a full deflection total current in the coil of approximately 0.0053 ampere for 80 volts, 0.0073 ampere for 110 volts, and 0.0083 ampere for 125 volts; the energy absorbed is therefore negligible.

For the ammeter, which is to be connected by a shunt across a resistance in series with one leg of the line, the potential at the coil terminals is readily obtained by connecting a "shunt" in the line whose resistance will be that which will ensure the appropriate potential for the coil; that is, since the potential between any two points of a wire (drop) is equal to the resistance between those two points multiplied by the current in circuit, or $C \times R$, it is only necessary to so proportion the resistance between the points of connection of the coil terminals as to obtain the appropriate

potential for the coil. The resistance is small and represents a negligible amount of absorbed energy. For switchboards the ammeter shunt is made up as a block of copper and resistance strips, the ammeter being connected by flexible leads to contacts on the shunt, which contacts must be on the blocks to obviate errors due to joints; this method obviates running extra bus bars or cables to the instrument. Each ammeter, its flexible leads, and its shunt are given the same number that all may be used together; the leads and shunt will differ for each instrument and must be used with that instrument only; the leads are included in the resistance of the instrument circuit and, obviously, must not be altered. A number of shunts are sometimes used for test instruments; one shunt has a resistance which gives the readings of the scale as marked; a second has but one-tenth of this resistance and produces but one-tenth of the potential (and deflection) of the first, hence the readings for this shunt are to be multiplied by 10; a third has but one one-hundredth the resistance of the first and the readings for this shunt are to be multiplied by one hundred, and so on; hence the original scale of the ammeter can be made available, by changing the shunt, to record 10, 100, and so on, times the scale reading. More frequently the instrument scale is marked to give a direct indication of the actual reading due to the shunt employed. Without its shunt the ammeter is a sensitive millivoltmeter.

The resistance material for voltmeter resistance and the ammeter shunt is an especially prepared alloy having a zero temperature coefficient; but the condition is, for the portable type (having a copper shunt within the instrument), more exact for a temperature assumed by the resistance material at the expiration of two minutes than before or after.

The circular type of voltmeter and ammeter is shown mounted on the switchboard of Fig. 219. It is a practically water-tight type, having an inner chamber in which the connections are made, and into which the leads are run water-tight; the case cover is secured against an annular packing.

The portable voltmeter is similar in appearance to the portable ammeter of Fig. 232. It is a double-scale instrument, reading 0 to 150 volts or 0 to 15 volts, accordingly as the connections are made to a binding post marked *A* or a binding post marked *B*, the difference in reading being effected through a section of the

same series resistance, 1500 ohms in the first case, and 15,000 ohms in the second. A key is inserted to make and break the circuit as desired, and may be held down or released by turning the hard rubber cap.

The portable ammeter is shown in Fig. 232. The portable ammeter has its shunt block enclosed in the case.

Weston instruments are designed to be used either vertically, or horizontally, or at an angle, but accuracy requires that they should be calibrated for the particular position of general use.

FIG. 232.—Weston portable ammeter.

Although the casing is intended as a magnetic shield, the instruments should be removed as far as practicable from the influence of extraneous magnetic influences. Similarly an instrument should not be used in close proximity to iron, such as a deck or bulkhead, and thus decrease the flux through the air gap; this will cause the instrument to read importantly lower than the actual.

In using a double-scale voltmeter, the higher scale of the instrument should be first used unless it is certain that the voltage is within the range of the lower scale; the resistance wire may be as low as 0.001 inch in diameter and would burn out at 150 volts; to prevent a burning out of ammeters it is the rule to install one of higher capacity than the maximum intended load.

Weston Ground Detector.—This instrument, shown on the switchboard of Fig. 221, differs from the voltmeter in the method of placing the coil and in having its zero in the center of the scale, reading up to standard voltage on two scales, one on each side of a central zero. As explained below, the pivot of the lever switch is connected to one terminal of the fixed resistance and moving coil; the other terminal is connected to ground.

Referring to the diagram (Fig. 233). If the lever 1 is connected to 4 and the positive leg of the circuit, and there is a ground on the positive leg, no current will pass through the instrument resistance (and coil) to ground, as the ground 2 is parallel with 4 and the potentials at the instrument terminals due to the two sources are practically equal and opposite. But if the

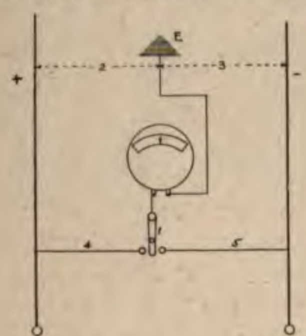


FIG. 233.—Diagram illustrating action of Weston ground detector.

negative leg is grounded, 3, a current will pass from 4, by 1, through the resistance (and coil) of the instrument by E and 3 to the negative leg, and the pointer of the instrument will deflect to the left hand as looked at. It will be noted that the resistance of the instrument and the insulation resistance of the negative leg are in series with each other. The conditions for the connection of 1 on 5 will be similar to those of 1 on 4, but the current will pass oppositely through the instrument via the ground at 2 and the pointer will deflect to the right-hand side of the scale.

The deflection in each case is used to determine the approximate insulation resistance in ohms of the connected circuit in the following method of calculation. The fundamental proportions depend upon the principle that the drop in potential in any two portions of a series circuit are proportional to their resistances; *e. g.*, if R and R' denote two resistances in series and C the cur-

rent flowing through both, then $CR = E =$ drop in R, and $CR' = E' =$ drop in R', from which $R : R' :: E : E'$.

Let $A =$ Voltage of a circuit to be tested (line voltage).
$B =$ Resistance of the ground detector employed.
$C =$ Deflection obtained when the positive leg is grounded.
$D =$ Deflection obtained when the negative leg is grounded.
$X =$ Resistance in ohms of negative leg side to ground.
$Y =$ Resistance in ohms of positive leg side to ground.

The fundamental consideration is that both the positive and negative legs (2 and 3, Fig. 233) are grounded, and that 1 is connected to 5. The conditions are: first, a current can pass through the instrument resistance and ground 2 to the positive leg and, these resistances being in series, there will be a deflection on the right-hand side of the scale of C volts; second, the ground 3 is in parallel with 5, and its terminus at E has also a potential in parallel with 5, and somewhat affecting the potential C. The drop through Y ohms will evidently be equal to $A - C$, hence

$$C : A - C :: \frac{1}{\frac{1}{X} + \frac{1}{B}} : Y \qquad (1)$$

For the contact of 1 on 4:

$$D : A - D :: \frac{1}{\frac{1}{Y} + \frac{1}{B}} : X \qquad (2)$$

Combining:

$$X = B \frac{A - C - D}{D} \qquad (3)$$

$$Y = B \frac{A - C - D}{C} \qquad (4)$$

If the circuit is grounded on the negative leg only, C will be zero and

$$X = B \frac{A - D}{D} \qquad (5)$$

If the circuit is grounded on the positive leg only, D will be zero and

$$Y = B \frac{A - C}{C} \qquad (6)$$

B is marked on the instrument as on other voltmeters. A graphic chart is usually supplied to ships from which X and Y can be picked off.

When testing insulation resistance with this instrument, a closer approximation is obtained by having but one generator on the bus bar and testing out one circuit at a time.

Caution: 1. It is better not to use the instrument until the circuit under test has been first tested by the lamp detector. 2. Be careful not to touch the live parts of the instrument, or leads, with the hand or fingers this would shunt the insulation resistance under test through a comparatively small resistance, and the resulting deflection would be for the two resistances in parallel, not for the insulation resistance alone.

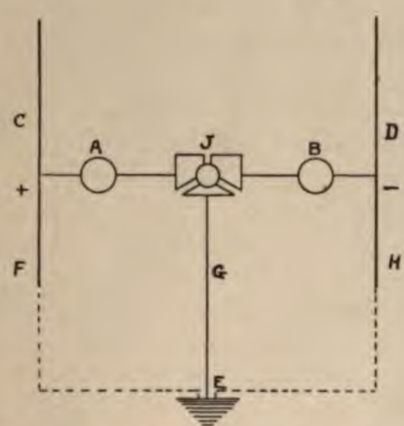


FIG. 234.—Diagram illustrating action of lamp ground detector.

In the portable type of instrument a binding post is supplied at the top for the ground wire. At the bottom, on each side, is a binding post for the connecting wires and also a push key which connects its terminal to a switch bar (inside), to which bar the instrument resistance (and coil) are connected; the negative leg of the circuit is connected to the left hand (marked —) lower binding post. To test for a ground on the negative leg, the push key on the side marked + is pressed; for a ground on the positive leg, the key marked —. The same formulæ apply to this instrument. The push keys and contacts are covered with hard rubber, preventing any shunting effect in handling. In late types

but one push key can be operated at the same time, thus obviating any chance of short-circuit.

Lamp Ground Detector.—The office of this instrument is mainly to indicate that a ground exists on a circuit, and it will only so indicate when the insulation resistance of the circuit is very low.

The lamp detector consists of two 16 c. p. incandescent lamps installed in series between the positive and the negative bus bars of the switchboard, the series connection being made through a plug switch, the plug also switching in the ground connection.

In the diagram (Fig. 234), *A* and *B* are the two 16 c. p. lamps, *A* connecting to the positive bus bar, *C*, and *B* connecting to the negative bus bar *D*. *J* is the plug switch with connections to *A* and *B*, and also, by *G*, to earth (a wire attached to a convenient metal part of the ship which is the metallic connection with the outside water).

If the plug is inserted at *J*, three cases arise:

I. Both *C* and *D* are free from grounds.

In this case there will be no connection of *C* or *D* with earth, and the current will flow from *C*, through *A*, *J*, and *B*, to *D*. *A* and *B* being in series, the sum of their resistances is added to that of the lead wires and this doubled resistance, at the normal potential between *C* and *D* causes them both to burn a dull red; that is the double resistance causes the potential at the lamp terminals to be but half of that required when either *A* or *B* is to burn brightly.

II. There is a ground on *C*.

In this case *C* is in communication with earth, the current flowing by *F* to *E*, by *G* to *J*, and thence by *B* to *D*. Hence, if there be a dead ground on *C*, *A* will be short-circuited through *F*, *E*, and *G*, and will be extinguished, while *B*, being no longer in series with *A*, will receive the full potential of the line and will burn brightly; if the ground on *C* be not a dead ground, *B* will be of a brighter tinge than *A*, the current dividing between earth and *A* in inverse proportion of their resistances.

III. There is a ground on *D*.

In this case *B* will be extinguished or dimmed, the current passing from *C*, through *A*, *J*, *G*, *E*, and *H* to *D*, or dividing at *J* through *G* and *B*.

From cases II and III it will be seen that that lamp is the dimmer which is directly connected with the grounded circuit.

The lamp detector is not a delicate test for grounds, it merely gives warning of any approach to low insulation resistance in the

FIG. 235.—Hand tachometer and hand speed counter.

circuit. The circuit on which the ground exists is discovered by elimination, opening one circuit switch after the other until both lamps, *A* and *B*, glow alike.

Tachometer (Fig. 235, left).

This instrument is a direct-reading speed register; its construction is based upon centrifugal force and consists essentially of a pendulum ring pivoted on a central shaft. The ring is normally held at an angle to the shaft, when at rest, by two carefully calibrated springs. When the shaft revolves the ring tends to assume a position in which its plane is perpendicular to the shaft, which tendency is resisted by the springs. The action of the ring is transmitted to the pointer through a link work motion, the pointer indicating the number of revolutions on the calibrated scale of the dial; having carefully aligned the tachometer with the mechanism under test, the instrument will prove quite dead beat.

For readings within the scale range (ordinarily 1000), the driving point is directly attached to the central shaft; its sleeve is split and holds to the shaft by friction.

A wide range of usefulness for the instrument is provided by two sets of gears, the revolutions of the driving point being transmitted through these gears to the shaft instead of directly; one set drives the tachometer shaft at double the speed of the mechanism under test and ensures greater accuracy in the measurement of low speeds; the other set reduces the revolutions one-half, thus providing for speeds up to twice the scale reading of the instrument. Each set of gears has a specially adapted sleeved spindle (stamped for the speed) which carries a cog wheel on its inner end and is continued beyond the sleeve as a spindle over which the driving point is to be slipped, the driving being accomplished by a through pin on the spindle and scores on the inner end of the driving point. There is also a sleeve having two cog wheels which is slipped over a slide post attached to the case and held by a follower; the inner cog wheel of this sleeve engages that wheel which is permanently attached to the instrument shaft, the other engages the cog wheel on the sleeved spindle. Since the sleeved spindle journals loosely on the shaft, the driving point drives this spindle which in turn drives, through its own cog wheel, the cogs of the sleeve on the side post and that on the shaft.

Hand Speed Counter.

The Starrett type, a common supply, is shown in Fig. 235, right. The spindle carries a worm (inside the casing) which

engages the cogged gearing of a wheel attached to the outer dial. The dial is marked for 100 divisions, reading both to the right and to the left. At each revolution of the outer dial a lug inside engages a pin of the inner dial and moves this dial one indication; the indications are recessed to take a spring pointer, which acts as a detent to the inner dial. The spindle is pointed and bevelled to take on the shaft center of the machine whose speed is to be tested; it is also provided with a sleeve tipped with a rubber cone which can be slipped over the point when the use of the sharpened point is not applicable or desirable.

The handle is of hard rubber and is sometimes made with a spring clutch grip to engage the worm only when the grip is pressed.

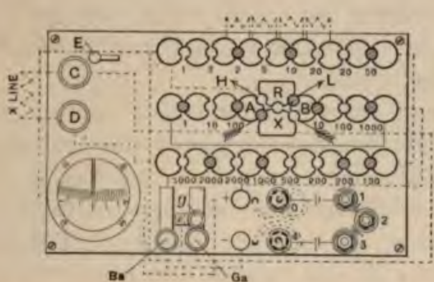


Fig. 236.—Connections of acme testing set.

The hand counter must be timed by a time-piece, and is therefore inconvenient as compared with the direct-reading tachometer; it is valuable as a check on the tachometer readings.

Testing Set (Acme).

The plan of this small box of resistance coils, or bridge, is shown in Fig. 236, and is a somewhat different arrangement from the more common forms of bridge in that the bridge (ratio) arms are in the second row and have a commutating block to transpose the two ratio arms, *A* and *B*, so that they are passed through in the reverse order.

The top row of blocks is connected to the bottom row by a heavy copper bar which joins the right-hand (50 and 100) blocks; these two rows together constitute the known resistance, or rheostat, and cover any resistance from 1 to 11,100 ohms on removing the proper plugs. The lower left-hand block (5000) is

connected to the lower line post *D*. The upper line post *C* is connected to block *X*; this block *X* has no other permanent connection excepting that it is joined to the galvanometer key. The block *R* is connected to the upper left-hand (1) block of the rheostat and has otherwise no connection except by plugs. The end blocks (1 and 1000) of the middle row are connected together by a heavy copper bar; each half of this now constitutes a bridge arm, designated *A* (to the left) and *B* (to the right). Starting from the lower line post *D*, the circuit is continuous from there, through the rheostat, and then through first one bridge ratio arm and then the other, back to the line post *C*.

The function of the commutator is merely to transpose the bridge arms *A* and *B*, so that they are passed in reverse order. All the above connections are in circuit with the resistance to be measured and are therefore made heavy to add no appreciable resistance to the circuit.

The two battery terminals marked + and —, are connected. one directly to the junction common to the two bridge arms, the other through the battery key to the rheostat. The two galvanometer terminals are connected, one directly to the block *R* or, what is equivalent, to the upper left-hand (1) rheostat block, while the other connects through the galvanometer key to the block *X*. The blocks *A*, *B*, *R*, and *X* can be connected by plugs The connections described from the three arms of a Wheatstone bridge, the fourth arm being the resistance to be measured which is to be connected to the line posts *C* and *D*.

When the commutator plugs are inserted as shown in Fig. 236, $A:B::X:R$, but if placed in the other diagonal $A:B::R:X$.

There are four dry-cell batteries, and 1, 2, 3, or 4 cells can be used by placing the caps of the flexible lead of the negative connection on the cell of number corresponding to the number of cells required.

To measure a resistance. Connect the terminals of the resistance to be measured to the line posts *C* and *D*, and place the negative battery connectors on battery 1, this throws one cell of the battery into circuit which is sufficient until balance is roughly attained. Unplug the 100-ohm coil in each bridge arm, and place the commutator plugs as desired for ratios as per table below. Remove plugs from the rheostat until the aggregate resistance unplugged is, as nearly as may be guessed, equal in value to that

of the unknown resistance. Then press the *battery key*, and, *holding that down*, momentarily press the galvanometer key. If the galvanometer needle swings toward +, the resistance unplugged in the rheostat is too high and should be reduced. If the deflection is toward —, the resistance is too low and should be increased. By altering the resistance in this way a value will soon be found wherein a slight change either way will reverse the deflection of the galvanometer needle. The rest of the battery may now be put in circuit by placing the negative battery connector on 4. If the keys be again pressed, *first the battery key, then the galvanometer key*, a greater deflection will be obtained than before for the same variation in the rheostat, and, therefore, the adjustment can be made more accurately. With

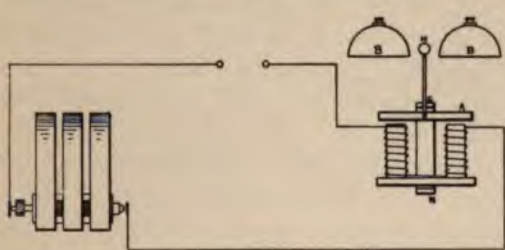


FIG. 237.—Diagram of magneto connections.

bridge arms of equal value this is the best result that can be obtained, but by selecting more suitable values for the two arms a considerably higher degree of accuracy may be secured.

The following table shows the value of A and B, respectively, to be chosen when measuring any resistance within the range of the set:

Below	1.5	ohms, make	$A =$ 1,	$B =$ 1000
Between	1.5 and 11	" "	$A =$ 1,	$B =$ 100
"	11 " 78	" "	$A =$ 10,	$B =$ 100
"	78 " 1100	" "	$A =$ 100,	$B =$ 1000
"	1100 " 6100	" "	$A =$ 100,	$B =$ 100
"	6100 " 110,000	" "	$B =$ 1000,	$A =$ 100
"	110,000 " 1,110,000	" "	$B =$ 1000,	$A =$ 10
"	1,110,000 " 11,110,000	" "	$B =$ 1000,	$A =$ 1

Testing Generator, or Magneto.

This instrument is of the alternating current type commonly seen in connection with telephone service.

Its field is made by three horseshoe, permanent magnets having

soft iron pole pieces which closely embrace the long, Siemens type, shuttle-wound armature.

The armature is revolved by a train of wheels actuated by a hand crank.

The armature circuit is wound with No. 36 B. & S. G. wire and has a resistance of 1700 ohms (differing for types of manufacture), corresponding to a length of about 4100 feet for that resistance. The coil ends are attached to two insulated collector rings on which the brushes take. The alternating voltage at the terminals for maximum speed is from 30 to 40 volts.

Within the box case is a "ringer" having a clapper (Fig. 237) which swings between two gongs. The clapper armature vibrates between the two electromagnets shown, which are so mounted on one end of a permanent magnet as to be polarized, that is, when no current is passing, the cores of the electromagnets will be similarly magnetized, and their upper ends, opposite the soft iron armature to which the clapper is attached will be of the same polarity. The soft iron armature, which is mounted on the opposite pole of the permanent magnet, will be usually attracted to one of the electromagnets. The coils of the electromagnets are wound in opposite directions; when a current passes, the magnetism of one electromagnet is strengthened and that of the other weakened; the current being alternating the clapper is swung from one gong to the other for every revolution of the magneto's armature.

The magneto will not ring through a resistance greater than 50,000 ohms, hence it is not available for testing insulation resistances, except that if it will ring it shows that the ohmic insulation resistance is 50,000 ohms or less. Its chief use is for testing the continuity of a circuit.

CHAPTER XII.

GENERAL NOTES ON GENERATING SETS AND MOTORS.

The essence of proper endurance and successful operation of an electrical plant resides in an interested attention on the part of the operating force and a careful inspection of that attention by authority. The elements of attention are:

1. Scrupulous cleanliness.

2. Thorough water-tightness, maintaining the integrity of the water-tighting designs as installed.

A particular case of this is the prevention of access of salt water, that inveterate enemy of electrical appliances on board ship which corrodes connections and forms short circuits and grounds through the resulting copper salts all of which are, more or less, electrical conductors.

3. Sound connections.

The mere oxidation at connections introduces resistances which prevent the proper functioning of appliances, dissipate the electrical energy in heat and cause unauthorized losses. Loose connections are always bad practice and necessarily faulty.

4. Timely repairs of faults.

The " stitch in time " is mandatory in mechanical and electrical faults, tending as they do to become rapidly worse and, generally speaking, a bill of repairs may be taken as the inverse measure of this element of attention.

The Engine and Its Connections.

The type of engine for driving dynamos, etc., at a high rate of rotation is known as a high-speed engine, the separating line from a low-speed engine being generally accepted as at from 200 to 250 revolutions per minute. The type also differs from general engine designs in having a short stroke. The combined features of high speed and short stroke place the type in a class of itself—distinct from the high-speed types for locomotives, torpedo-boats, and the like—and requires distinct elements of design which may

be noted in the peculiar appearance of its normal indicator diagram. The distinct advantages of the type are compactness, lightness, and great strength; as to efficiency and economy, experiments with over 100,000 horsepower indicate that these factors are quite equal to those of other types for similar capacity. The explanation is found in the better lubrication of the working parts, and in the better distribution of stress by reason of the increased inertia due to the high rate of reciprocation of the pistons.

Efficiency and economy are important factors in the final criterion of the performance of an engine and their practicable evidence is the expenditure of coal, developed in the engine as a consumption of steam; as the efficiency is dependent upon this steam consumption, a final criterion of performance (durability apart) may be said to rest on water consumption. Coal endurance is ever a serious question in a man-of-war, and excessive water consumption in auxiliary engines results in a cumulative demand on the coal supply.

The necessary waste steam consumption in an engine is usually distributed amongst four well-established sources of loss: Clearance; port friction; condensation, and leakage.

Clearance must be provided for easing the racking strain of fast piston reversals, and must necessarily increase in percentage as the number of reversals is increased. The volume of clearance in any given pattern of engine varies with the area of the piston and is nearly independent of the length of stroke; but when expressed as a percentage of the volume of the cylinder it will increase as the stroke diminishes—the usual 3 per cent on a 5-foot stroke would become 36 per cent if the stroke were reduced to 5 inches. This clearance loss is severe in all high-speed engines and is practically constant for a type.

Port friction may be defined as a sort of added clearance; it is the volume necessary for the ports combined with a choking of the steam in its passage to the cylinder. This loss is nearly a minimum in dynamo engines having piston valves, as the ports are fairly large and straight; in those which have flat valves the ports are curved to an approach to a right angle and port friction is often greater for this type of valve than for piston valves.

Condensation is found in all reciprocating engines, and is principally due to the fact that the wall of the cylinder is alternately exposed to high and low temperatures. The temperature

difference between the low and high temperature approximates 180° C., or the temperature difference between boiling water and ice. In a compound engine the temperature difference is approximately halved in each cylinder, with necessarily great reduction in condensation. It is obvious that the rate of cooling will vary with the time of exposure, that is, it will be less with increased speed, and in general it is established that there will be a saving of nearly one-half by doubling the speed. This is only an approximation, however, as part of the condensation is due to the radiation to the atmosphere, and another part to the direct conduction of heat from the cylinders to the bed-plate and working parts of the engine, a condition noticeable in some enclosed engines. Steam jacketing is naturally suggested as a remedy for condensation, but in small engines, even when compound, the gain in the cylinder is so evenly balanced by the large loss in the jacket as to render the expedient expensive and unnecessary.

Leakage is an inherent vice of piston valves and is much increased by wear, causing back pressure and increased loss from that source; it appears in the cylinders as well, as the pistons wear. Valve leakage will be readily understood when it is stated that from this loss alone it has been found that an engine apparently in good order, even when standing still, took as high as 30 to 40 per cent of its normal requirement of steam; and, though the automatic governor handled it well as a new engine, and when running without load, it ran practically independent of the governor under the new conditions until loaded to about 20 per cent. It is quite practicable to overcome the wear of piston valves by packing rings. Packing a piston valve requires bridges in the ports and that the bridging be diagonal; this involves an expense which would be expensive in casting, but is accomplished by a cast-iron bushing (liner) in the valve chest with appropriately bridged ports. It is not worth while to put packing rings on the small horsepower valves as they can readily be turned from spare rough castings.

From 15 to 25 per cent of the steam delivered at the throttle is the plain statement of the summation of these four losses in a new dynamo engine that has been subjected only to those preliminary trials necessary to put it in proper order for turning over to the ship and the statement is believed to be conservative. The remedy for large water consumption is more closely fitting valves

and, in engines not so fitted, packing rings on the piston and on the L. P. valves if of the piston type. The ship fault of throttling down is to be noted as a means of increasing water consumption. Throttling down is sometimes practiced to reduce pressure when running under light loads, and is done under the impression that it saves steam, and also for the reason that a weight spring governor is inclined to be noisy at small loads if the throttle is wide open; since the fit of piston valves is what is known as an expansion fit, the best results being obtained at the steam temperature of the standard pressure of the design throttling down, reducing pressure, and therefore temperature, will promote leakage. At any load the governor will regulate the expenditure of steam more efficiently than any attendant at the throttle, and it should be the invariable practice to run at the prescribed number of revolutions as shown on the name plate, with the throttle wide open, and let the governor take care of the steam as it was designed to do. The noise of the governor due to carrying too light a load is readily remedied by switching on a ventilating blower, or the lights of a circuit which does not affect the overhead lights of the sleeping quarters of the men, and the extra load will actually cause no additional consumption of steam owing to the reduced leakage in the valve.

In the following remarks on engines, many conditions are those which are met with in engines in general but it will be remembered that wear and tear are much enhanced in short-stroke engines by high speed, and non-oiling cylinders and valve chests; the use of oil in cylinders has passed beyond the pale of recognition as it is certainly demonstrated that the oil considerably shortens the life of the main boilers and condensers, hence the *onus* is thrown upon the engine.

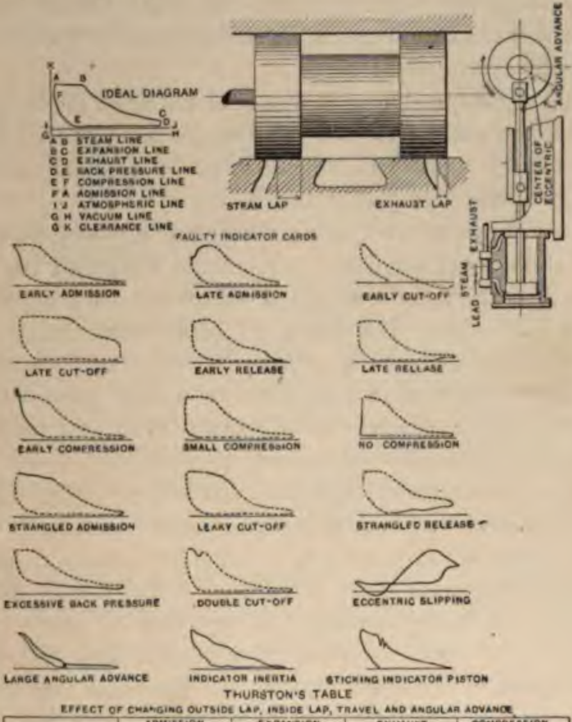
Vibration.—The effect of this fault on working parts and connections can aggravate many others, but the immediate effect is the loosening of joints in the piping. If vibration can be detected to a sensible degree when standing at any point near the periphery of the foundation the fault is important enough for correction. The method of repair must be determined for the particular case and the construction of the compartment and the deck underlying the dynamo-room.

Noise.—All noise should be eliminated. Apart from noise due to lost motion and wear, the following may occur:

Chattering of Check Valve in the Drain Piping.—The valve should be taken out and the seat fitted with asbestos washers.

Chattering of the Reducing Valve.—This will often occur if the valve is installed on a vertical pipe instead of on a horizontal.

Chattering of the Exhaust Check Valve.—The valve is not an indispensable attachment; the fault can best be relieved by the removal of the valve.



THURSTON'S TABLE

EFFECT OF CHANGING OUTSIDE LAP, INSIDE LAP, TRAVEL AND ANGULAR ADVANCE

	ADMISSION	EXPANSION	EXHAUST	COMPRESSION
INCREASING OUTSIDE LAP	IS LATER CEASES SOONER	OCCURS EARLIER CONTINUES LONGER	IS UNCHANGED	BEGINS AT SAME POINT
INCREASING INSIDE LAP	IS UNCHANGED	BEGINS AS BEFORE CONTINUES LONGER	OCCURS LATER CEASES EARLIER	BEGINS SOONER CONTINUES LONGER
INCREASING TRAVEL	BEGINS SOONER CONTINUES LONGER	BEGINS LATER CEASES SOONER	BEGINS SOONER CEASES LATER	BEGINS LATER ENDS SOONER
INCREASING ANGULAR ADVANCE	BEGINS EARLIER PERIOD UNALTERED	BEGINS SOONER PERIOD THE SAME	BEGINS EARLIER PERIOD UNCHANGED	BEGINS EARLIER PERIOD THE SAME

Fig. 238.—Illustrating the interpretations of indicator cards.

Whistling or Grunting in the Cylinder or Valve Chests.—This is an indication that the lubrication of the pistons and valves is insufficient from the wire-drawn steam; it will only occur when running with light loads and will disappear when extra load is switched in and the engine takes more steam.

Water Hammer.—This commonly occurs in starting up. Thorough warming up beforehand and starting slowly with all drains open will remedy it (see also water in the cylinders).

The Cylinder and Valve-Chest Assembly.—The covers should be removed at least once in six months and the interior examined to see that the pistons and valves are secure on their rods and the cotter pins in place and for any corrosion or scoring of the working parts or their faces and seats, the wear on packing rings and the condition of the stuffing box of the intermediate head (tandem-compound).

The rod packings should be intact at all times or oil will work into the steam and be carried over to the boilers; that the packing is loose or worn will be indicated by escaping steam, this applies particularly to the high-pressure cylinder.

The correctness of the *valve settings* are indicated by the cards which should be taken weekly and made a part of the journal. In Fig. 238 are shown the accepted interpretations from variations from the ideal card. Normal good cards show that the design contemplates wire drawing after admission, early release, and considerable compression also that the initial pressure for the bottom end of the stroke is to be greater than that for the head end, which is to assist in handling that weight of the working parts which is not counterbalanced. It will often be found that the work done in the high-pressure cylinder is from 3 to 5 per cent in excess of that shown by the low-pressure cards and results partly from the extra work done in the bottom end of the cylinder, partly from diminution of pressure by condensation in the receiver (if used) and partly from the fact that the low-pressure valve is not controlled by the governor; in designs in which control of the low-pressure valve is introduced the percentage difference in work between the two cylinders is less, the device, however, is intended to lessen the steam consumption.

The available method of setting a valve is to lengthen or shorten its position on the rod, checking the setting by the results shown by the indicator card. The valve can be assembled on the rod most frequently in but one way; the lap and lead being constant for the design, which is for the normal steam pressure and prescribed number of inches of vacuum, it follows that the valve will not so well equalize the distribution of work in both cylinders at any other pressure and at any other condition of vacuum. Work-

ing at 20 per cent below the normal pressure on atmospheric exhaust the high-pressure cylinder may do two-thirds of the total work developed, and, thus doing twice the work of the low-pressure, the stress on the cranks is correspondingly divided and strain or bending of the shaft at the high-pressure end may ensue with heavy load; it is equally true of the low vacuum common to ship dynamo-room experience and is the potent argument for a separate, auxiliary condenser for the isolated service.

The Cross-Head.—It is the face of the cross-head guide bearing which develops the first wear in an engine. It is occasioned by the heavy friction of the reaction of the down-stroke thrust of the short connecting rod on the crank pin on a surface whose lubrication is at best difficult and unassured. Under running conditions the fault does not become apparent until lost motion produces an evident knock at the location and the necessity for lining up has become urgent.

In those cross-heads in which the blocks are held in jaws by straps, too much care cannot be taken that the strap nuts are well set up and locked; if the nuts become loose the hammering action of the piston, especially if assisted by water in the cylinder, can easily cause the nuts to strip the bolt threads, drop the nuts and strap into the base of the column, and catch the counterbalance of the crank when the clearance is small; on board one battleship such an accident broke the counterbalance and cracked the engine housing.

Careful attention should be paid to keeping the wrist-pin bearing blocks well lined, the pin and bearing well oiled, and to removing any knocking as soon as it develops.

A cross-head design which contemplates screwing the piston rod into a split sleeve and to be held by clamping is quite sure to prove annoying and defeat any but a tentative repair.

The Shaft.—The strain or spring or bend of a shaft is a serious matter as it involves heating of all brasses of the main bearings and of the cranks. Fortunately the bearings are placed as closely to the cranks as good clearance will permit and the accident is infrequent where the crank thrusts are assimilated, that is, where the work is fairly equalized between the cylinders. In a case of one small vessel on a speed trial the shaft of an engine was broken at the fillet of the L. P. crank; the accident has been attributed to the carelessness of an attendant in leaving open

the by-pass valve, thus creating a heavy preponderance of work in the L. P. cylinder.

The preservation of the truth of alignment of a shaft is necessary at all times, otherwise the bearings will heat and the armature be shifted from its proper position in the field and thrown out of magnetic balance.

Adjustments of the Shaft Itself when out of Line.—If the shaft is sprung or badly worn in the bearings, remove it and put it in a lathe between centers. If the shaft centers are not true with the surface of the ends make them so by scraping or by reaming by use of the steady rest. Try the shaft at each bearing and if sprung force it back as nearly to line as possible and turn down each defective bearing. If the shaft is worn oval, or flat in spots, or scored or tapered in the bearings, the only remedy is to turn down at each defective shaft bearing. The foregoing methods will insure a perfectly straight shaft, but require careful and skillful work.

In case a shaft is fitted to be coupled to the armature shaft the coupling must be faced, taking as light a cut as will clean up the entire face. Taking off too much metal must be compensated by liners when assembling in order to preserve the longitudinal alignment.

Adjustment of Bearings.—First take the diameter of each bearing on the shaft as the basis of alteration of the boxes. Many designs of boxes exist and each design has some difference in method of treatment. For boxes having white metal lining, or babbitt, the old lining should be removed, as a rule, if the shaft has been turned down or the lining is much worn. The lining is cut out by a cold chisel and the box thoroughly cleaned of oil and dirt by strong lye, benzine, etc., *the box not being removable.* The babbitting mandrel (or shaft in its absence) is then placed in position in the engine, and lined about 1/16 inch above the true center, to allow for filing and scraping and is firmly secured. The ends of the bearing boxes are walled up to hold in the molten metal, and the mandrel covered with lamp black or other suitable material which will prevent sticking. The metal used is commonly the Magnolia anti-friction metal, which is melted in a clean ladle and thoroughly stirred; it should not be mixed with other metal in the melting, but the old metal of the bearing can be melted over and used again by adding a little new; the metal

is to be heated sufficiently to flow freely and extreme heat should be avoided, when hot enough to brown a pine stick and trembling in the ladle, it is ready to pour. Before pouring, any likelihood of sudden chilling of the metal before it can properly fill the box is forestalled by heating the mandrel and box by an oil torch to about 200° F.; this precaution also effects a smooth and even bearing surface and partly overcomes the shrinkage. Pour the metal carefully, in a copious and continuous stream until the box is full, slacking down and adding a small excess to compensate for the shrinkage. When all the bearings are filled and the metal has cooled, remove the mandrel and trim off all surplus metal.

Next coat the shaft bearing, thinly and evenly, with a mixture of lamp black and machine oil of the consistency of pasty shoe blacking; place the shaft in place in the boxes and turn over a few turns by hand, then take it out; any high spots in the boxes should show a stain, and should be scraped or filed down; trial by the shaft is again made and the process repeated until all bearings show a perfect wearing surface. The method should be pursued carefully in all instances that, when completed, the shaft may lie truly in line in all of its bottom boxes. The oil grooves are cut before the final scraping.

The top half of the box is treated in much the same way as the bottom, the same process of fitting being followed. Particular care should be taken to keep the bore parallel with the joint, that the top half may joint fairly and the bore bear fairly on the shaft when the binder is put on and is tightened down. It is good practice to insert liners in the joint which can be removed as the babbitt wears.

When the boxes are removable, the new lining should be cast to be about ¼ inch or more smaller than the true bore and bored to size. Circular boxes can be chucked and bored true with the outer circumference; rectangular, or other than circular boxes are bored in the lathe by chucking or clamping to an angle plate; in either case, good lining up when placed in the engine demands careful work.

Bearing brasses made up of bronze, or other metal without white metal lining, are often lined up by building up on the bottom of the lower half until the center of the bore is higher than the shaft center, and the whole is then rebored for the proper

center. Sometimes the two halves are bored and lined with babbitt, but this is not necessary when the original type of brass has proved satisfactory. It is not advisable to repair badly worn brasses. The method of fitting of brasses to the shaft is the same as that for lined boxes.

When the shaft and bearings have been assembled in the engine the shaft should turn freely without appreciable lost motion. The engine is now run slowly under steam for a sufficient time to determine that no bearings heat; next the speed is increased and a run of an hour made without load, after which a light load is put on and gradually raised to the maximum, and the engine run under full-load conditions to determine that there is no heating or pounding. When the engine has been run under load for a few days, any lost motion should be taken up at the bearings and the bearings examined and refitted, this should be continued every three or four days until no longer necessary.

When the bearings are close, keep them snug but do not bolt down too tight.

When a babbitt is too soft it can be hardened before boring out by peening. Begin at the middle and strike lightly at first, increasing the strength of the blow until the metal is sufficiently hammered. This must be very carefully done, if at all, as with small boxes distortion is likely to result.

The following process will insure the soldering of Magnolia metal in cast iron, brass, etc.: Heat the box about 200° F. and wash over with soldering acid; next rub on tin, and then pour the metal.

Crank Pin.—There is no manner of use in temporizing with a hot crank pin. Shift the load, shut down slowly, cool off the pin and examine, refit and readjust the boxes. The crank should be tested from time to time with the hand whilst running and upon the detection of decided or uncomfortable warmth, the engine should be stopped before the babbitt is affected. For those cranks requiring brasses the metal should be a hard bronze and true bored in a lathe.

Water in the Cylinder.—This condition is much dreaded in engine operation since, as water is incompressible, the piston (and perhaps valve) strikes an unyielding obstacle in its path; the results on the heads or working parts of the engine, and the extent of damage is dependent on the proportion of the clearance which

the water occupies at the end of the stroke; it is usually evidenced by a pounding within, known as water hammer, should nothing else occur. The final cause is that water is entrained in the steam and is condensed within the cylinders or chests, but mainly in the high pressure cylinders of compound engines. It is anticipated in design by a large factor of safety (4 to 5) in the thickness of the cylinder walls and by relief valves at the top and bottom of each cylinder through which the water can escape. A separator is installed on the steam line whose office it is to remove all water ordinarily entrained in the steam.

The shipboard causes that may occasion that excess of entrained water which can reach the cylinders or chests in volume (not including the common case of starting up and which is to be handled by the drains) are:

Insufficiency in the Capacity of the Separator.—The average separator which is installed is too small in volume. The volume should be fully four times that of the cylinder which is being supplied, and for a plant, four times the volume represented by the aggregate volumes of a cylinder for each engine, that is, having four compound engines, the separator volume should be 16 times the volume of any high pressure cylinder; having simple engines, 16 times the volume of any one cylinder. This minimum volume has also the advantage of cushioning the steam pulsations and of preventing the often-noticed vibration of the pointer of the steam gauge dial. The ideal installation is an individual separator for each engine, having four times the volume of the engine's cylinder (as above); the nearer this ideal is approached the greater will be the protection afforded to that engine as regards water hammer.

The condensed water in a separator should show low in the gauge glass, or better, not show at all, if the trap connections are in good order.

Condensation in the Steam Piping.—This cause is most frequent in starting up and is the usual occurrence in connection with water condensed in warming up. The separator will accommodate the condensation in the piping back of it.

Foaming of Boilers.—What water the separator cannot eliminate must go on to the engine and the dynamo engines will get a large percentage of water from this source if installed low down in the ship. An especial case has occurred from the throwing of

heavy steam-driven machinery (such as that for turrets) on boilers which were of insufficient capacity for the total duty demanded.

Shifting of Boilers.—The changing of the steam supply from one boiler to another is a common cause of water-loaded steam. It will occasion no accident if notice is given to the dynamo-room in advance.

Carrying Too High a Water Level in the Boilers.—This will increase the moisture in the steam, for which the normal working of the separator is for the normal boiler level; a lower level will give drier steam.

The common commercial effect of water in the cylinder is the blowing off or breaking of the cylinder head or bonnet but the covers of a ship dynamo engine are now so strong comparatively that no case of yielding at that point has recently occurred. The results noted have been: broken piston; broken or strained piston and valve rods; broken cross-head; broken connecting rod (in one case the crank end coming up against and cracking the bed-plate); strained shaft, in one case beyond repair.

Lubrication.—The lubrication of a journal effects three purposes: *the first* is that it prevents that heating of the journal and bearing due to friction which would expand both, seizing and stopping the motion; *the second* is that it reduces the mechanical losses of the engine due to friction; *the third* is that it reduces wear.

There are two methods of oil feed, gravity feed and forced feed.

The gravity, sight feed is accomplished by dripping the oil from oil cups or from a header filled from a suspended tank, the dripping into the feeder tube being in plain sight. This system requires extensive oilways in large bearings but the oil tubes can be tested before starting up by observing that the oil drips from the lower end of the oil tube on its bearing or into its pocket. The disadvantage of the system is that oil is not delivered in sufficient quantities to obtain the results of forced lubrication.

The great *advantage of forced lubrication* is that a large volume of oil is continuously forced through the bearings and around the journal. Its theory is that the metals are never in contact and it is intended that there shall be a flow, necessitating a clearance between the journal and bearing; hence if the pressure by gauge, about 15 pounds, is not maintained there is not sufficient amount

of oil to take up the clearance and lost motion and wear result. *For the mere purposes of lubrication* a pressure of from 1 to 3 pounds is ample, *but about 15 pounds is necessary to form the proper oil bearing.* A proper clearance between the bearing on the journals of working parts of engines, after they have been scraped to a fit, is an especially important matter with enclosed engines since the facilities for inspection are limited by the design of the castings; the solution resides in following the practice of adjusting the clearance by means of lead wires as used for main engines, where any cut and try method, involving possible heating and consequent delay, is obviously prohibitory. Lead wires of a diameter varying to suit the size of the bearing are laid on the journal and the bearing bolts set up hard; on slacking up the lead will be found to be flattened to the clearance dimensions and the thickness can be gauged. The lead wires are supplied in B. & S. G. sizes Nos. 10, 14, 16, 18, 20; fuse wire will answer in emergency. The mean clearance for journals is commonly about 0.01 inch; that for shafts, crank pins, and eccentrics (2½ to 6-inch diameter) is from 0.002 to 0.005 inch greater than the mean; that for wrist pins, valve stems, etc. (below 2½ inches diameter) varies about the same below the mean. To assist in the rapid and definite readjustment of the clearance in bearings, it is usual in repair work to separate the boxes and fill in the gaps with a set of liners. These liners are standardized in a set consisting of one each of No. 40 (0.003 inch), No. 36 (0.005 inch), No. 30 (0.01 inch), No. 24 (0.02 inch), No. 18 (0.04 inch) B. & S. gauge hard sheet-brass strips, shaped to conform to the edge of the boxes. The total thickness of one set is 0.078 inch. By using these in various combinations, any suitable clearance less than that existing may be obtained. Adjustments for length of connecting rods, valve rods, height of shaft bearings, and clearance of cross-head slides can also be made from the liners for the usual engine constructions. In fitting liners in bearings there should not be an excess of clearance at ends and sides through which oil may escape and reduce pressure.

The great drawback to present forced lubrication systems is that there is no means of assuring that the oil is feeding through the tubes, that is, that the tubes are not choked by gumming and foreign matter despite the pressure. Until a warmed bearing induces suspicion, it is assumed that the pressure will prevent the

condition. This points out the care that should be taken that all oil gets to the pump through the strainer only and not over the top or under the bottom; also that oil in the well which is apparently very dirty should be drawn off and carefully filtered.

A lubricating oil must have two qualifications: a density which will permit a flow in sufficient volume to fill the space between the box and journal; and viscosity, body, which determines its efficiency as a lubricant. Both are impaired by use, the density being increased and the viscosity lowered. To preserve working conditions and at the same time accomplish reasonable economy, about 25 per cent of clean (new) oil should be added to the dirty oil when running it through the filter.

No exact rule can be laid down as to the amount of oil to be supplied at starting; it will differ with the style of feed and make of engine. With forced lubrication a crank base should be filled to within 2 inches of the crank when at its lowest throw and the amount required be ascertained for the given case. The oil supply may be put in through the crank chamber door. All the tubes, chambers, etc., must be cleaned before, filling up and starting, from all dirt, sand, chips of paint, or other foreign matter, which can collect at the strainer and reduce the flow of oil below the necessary amount. In cleaning out the oil chambers, waste should not be used if practicable to use cloths; the lint from waste will clog up the pipes and strainers. Thoroughly clean out with lye all tubes, air vessels, and holes drilled in the shaft, cross-head, etc., not less than once every once in six months—to remove any gummy deposits. The first adjustment for the working pressure of 15 pounds may be made by the relief valve, if all other conditions are right, the excess returning through the by-pass pipe. The pressure gauge should be throttled by closing the cock to reduce the vibration of the pointer without reducing the readings.

The strainer should be lifted out frequently on a new engine and occasionally while using, to see that its surfaces are clear: this should be done often on starting up a new engine until it is certain that the tendency to clog up has been reduced to a minimum. Lifting the strainer does not interrupt the flow of oil, but it should be replaced as soon as possible to reduce obstructions in the pipe. The small holes in the top of the pump, for the return of any oil that gets up by the plunger, should be kept clear that the oil may have a free return to the chamber.

Any leakage of water through the stuffing boxes of the high pressure piston rod may overflow the oil chamber; the excess should be drawn off as required and put in the filter where the oil and water will be separated. The excess may be drawn off at the bib-cock in the piping from the pump. There is no gauge to indicate the excess but it may be noted when examining the strainer.

An excess of water mixed with the oil will lower the pressure on the system. Looseness of packings on the valve and piston rods will cause an excess of water and result in drawing the lubricating oil, which is thrown on the piston and valve rods into the steam spaces by the action of the vacuum. To obviate the effect, the packings should be examined frequently and adjusted as required.

The cool operation of the bearings may be noted by opening the door of the side of the engine frame, and feeling of the parts. The journals if in good order will not throw an objectionable amount of oil in the short time the door is open. If bearings are too loose or joints in piping are leaky, they must be tightened up If the check valves of the pump get worn in their valves or seats and reduce the pressure they must be refitted or renewed. In case of a lowering of pressure that cannot be compensated for by adjusting the by-pass, the bearing which requires taking up can be located by stopping the engine, disconnecting the pump plunger from its eccentric, and pumping up the pressure by hand; by doing this with the engine cranks at various portions of the stroke the slack bearing may be refitted and tested before use.

Arctic engine oil is a common supply for generating-set use and proves satisfactory. In first using this oil on engines which have been using other oils, the best plan is to fill the cups, etc., and run the engine at a moderate rate of speed that the oil may circulate and clean out all the channels. When the engine is stopped enough of the oil will remain to loosen all deposits. Run the first lot of oil about two days, then draw it off and replace with new oil filtering the dirty oil. After running the second lot four days repeat the operation and again fill up with new oil. When the filter shows clean oil begin using this on the engine. When the engines are in shape it is better to draw off the dirty oil from time to time, and filter, replacing with filtered oil; this,

with the forced lubrication, will keep the circulating system full of oil.

The best grease for grease cups is a good grade of Albany grease.

The oil in the outer, ring oiler bearing should not be quite up to the level of the bottom of the shaft or it may be carried over to the armature. The armature should always be carefully shielded from oil whether thrown on, coming from casing leaks, or by crawling on the shaft. **Never use any but new oil on this generating bearing.**

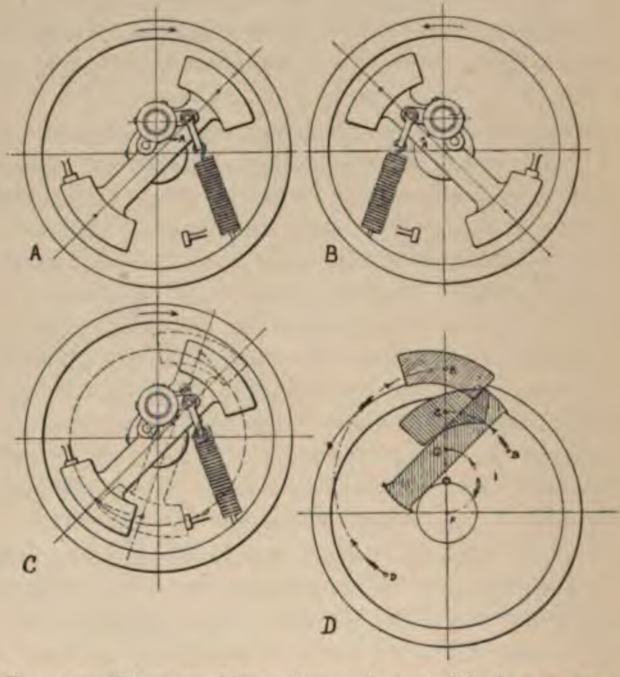


Fig. 239.—Diagram illustrating action of Rites' governor.

The Governor.—The type usually fitted to the engines is of the Rites design and, while simple in construction, contains features which require a proper understanding in order that the desired results in continued operation may be assurred.

The Rites' design of governor contemplates, primarily, the reduction to a minimum of the number of parts and journals in a

governor in order to obtain greater certainty and delicacy of action, including the faculty of regulating at the time when there is a tendency of the engine to change its speed rather than after the speed change has actually taken place. The governor action depends both on inertia and centrifugal force; the two are combined to mutually assist in producing the desired regulation.

In its simplest form the governor consists of a weight arm (Fig. 239) which lies in a circle on one of whose diameters lies the center of the shaft. The weight arm is enlarged at the ends for weights, giving it the appearance of a dumb bell from which is derived the colloquial term "dumb-bell governor."

The weight-arm pivot is located on a diameter about 45 degrees from that of the axis, and the stud, which acts as the eccentric and as the connection to the valve gear, is located between this pivot and the shaft center.

One end of the controlling spring is attached to the weight arm at a similar distance from the pivot and at about a similar angle to a line normal to that of the weight arm; the other end is attached to some fixed part, usually to the rim of the fly wheel.

The common assembly for either direction of rotation is as indicated in Fig. 239, *A* and *B*.

The adjustment of weight is so made that the center of gravity is at the point *A*, in figures A and B.

The part of the weight arm which produces the inertia effect is the longer as referred to the pivot, and is called the long arm; it will act very quickly at the time of a *sudden change of or a sudden tendency to change speed,* as in the case of the abrupt removal or increase of load. The short arm produces the centrifugal effect; the spring is attached to this end of the weight arm; this effect controls the *speed for gradual changes of loads,* changes of this nature not producing any effect on the long arm. .

In Fig. 239, *C,* the weight arm is shown, in full lines, at its position of extreme valve travel and in dotted lines at its position of minimum travel. The arcs of travel of the weights with reference to the point of suspension of the weight arm are indicated by dotted lines.

It will be seen that the center of gravity of the long, or inertia, arm is at a reduced radial distance from the center of the shaft, reducing the value of its effect as the position of minimum valve travel is approached; also that the center of gravity of the short,

or centrifugal arm, moves farther away from the shaft center under similar conditions, and consequently the certifugal effect tends to assume the greater and more powerful element in the combined effect. The action of centrifugal and inertia forces of the single governor weight may be best understood by first considering separately each of the three parts, which form the weights, viz.: the weight on the short arm, the weight on the long arm, and the arm which connects them.

In figure *D*, these have been drawn disconnected from each other and their centers of gravities are supposed to have taken the shown positions relative to the point of suspension and due to centrifugal force. The center of gravity of the weight on the short arm starts from the normal position at *B* and travels to *C* in the same direction as in the usual operation of the governor in getting up to speed with load. The center of gravity of the weight on the long arm starts from its normal position at *D* and travels to *E* contrary to the direction taken in the usual operation of the governor in getting up speed with load. The center of gravity of the connecting arm starts from its normal position at *F* and travels to *G* in the same direction as in the usual operation of the governor in getting up to speed with load. It will be seen from this that the weight on the long arm has an independent tendency to move in a direction contrary to that of the weight on the short arm and of the connecting arm. Therefore, its movement in speeding up the engine in starting and getting up to full speed with load is due to the preponderating effect of the weight of the short arm and the connecting arm. These two weights, then, are the controlling factors in the proper action of the governor and control in reducing the valve travel in starting up and also on any increase of speed.

The weight on the long arm does not contribute to this effect but by its disposition is free to lag behind and assist in reducing the valve travel and engine speed on sudden increase of speed, and to forge ahead and assist in increasing the valve travel and engine speed on any sudden decrease of speed.

For the general case, within certain limits, adjustments of operation of the governor are obtained by the combined changes of the table on following page (see also Note 14, page 180).

Function.		Parts to be Adjusted.					
		Weight on arms.				Spring.	
						Points of support.	
To be changed.	Change to be made.	Both.	Long.	Short.	Tension.	Outer.	Inner.
Speed.	More.	Less.	More.	Less.	More.	....	Out.
Speed.	Less.	More.	Less.	More.	....	....	....
Regulation.	Closer.	....	....	....	More.	....	In.
Regulation.	Less close.	....	....	....	Less.	....	Out.
Hunting.	Less.	....	....	More.	....	....	Out.

The Dynamo and Its Connections.

Notwithstanding the many details requiring careful construction, the dynamo, once it is designed and assembled, is a simple mechanical contrivance, if only from the small number of its working parts. Its management is reducible to a few simple principles, namely, the maintaining of designed speed, the maintaining of rated voltage, the maintaining of integrity of insulation resistance, and the avoidance of increase of losses.

Speed and Voltage.—The total electromotive force generated by an armature revolving in a magnetic field may for the purpose of this explanation be represented by the approximate formula $E = CMR$: in which C is the number of conductors cutting the lines of force; M is the intensity of the magnetic field; R is the number of revolutions per second, more commonly considered in its larger unit of revolutions per minute. C having been determined for any design ceases to be a variable; the matter of attention then reduces to the maintaining of the intensity of field and the speed in such a relation that their product shall always be constant.

The speed factor is dependent upon so adjusting the engine governor and its regulation that the speed shall be kept to that value at which it was designed that the armature should be revolved, that is, at rated speed.

The intensity of the magnetic field is obtained by a certain number of coils of wire, wound round the designed field core in which coils a fixed number of amperes of current is circulating; the product of the number of turns and the fixed number amperes is known as the ampere-turns, and this product must be a constant

to produce the required intensity. Since the number of turns is fixed in any dynamo by the designed field winding, the variable in operation is the current circulating in the field; therefore, for the given machine, the total electromotive force will be maintained if the speed is right and the current circulating in the field is as intended.

It is apparent that if the field current is too small, the speed must be proportionally increased; if the speed is too low the field current must make up the deficit. The limitations are: *first*, that the speed must not be increased to give that peripheral velocity which will cause sufficient centrifugal force to endanger the mechanical construction, and the governor should be adjusted to that rated speed of design in which this matter has been duly considered; *second*, that the field current should not be so increased as to unduly heat the coil.

Integrity of Insulation.—By insulation is meant not only the insulating coverings of current-carrying parts and the insulating material separating those current-carrying parts from contiguous metal, but also the air spaces separating connecting blocks and the like which may become bridged by conducting faults. The breaking down, lessening, of insulation resistance causing leakage, short circuits and grounds may occur from four principal causes, dirt, moisture (or water), oil, and heat.

The effect of dirt principally in the form of dust, is to absorb oil and moisture (or water) and form a conducting train to the framing or between points differing in potential, thus forming a leak, a short circuit, or a ground; or, in thus absorbing oil and moisture, to increase their particular effect on the insulations. Included in the designation of dirt is carbon and copper dust, substances which are continually thrown off from the commutator and which necessarily add to the conducting power of the train mentioned.

It is hereafter assumed in treating of faults that all dust, copper dust, metal chips, solder, and other foreign conducting matter are to be first cleaned off. **They must be the subject of first investigation when fault develops, the next investigation to be for effect of oil and moisture.**

The effect of moisture (or water) is to decrease the insulating qualities of insulations through the conducting properties of dampness, insulations not being satisfactorily waterproof; or

through direct connection between exposed conductors. An armature which measures low in insulation resistance may often test a megohm after wiping the ends of the commutator dry, the moisture having grounded the bars to the commutator shell.

The effect of oil, whether thrown on, by creeping, or when volatilized in the atmosphere and condensed, is not only similar to that of moisture, but it softens and injures the insulating constituents of the insulation, particularly rubber and varnishes. Oil necessarily forms more stable and lasting trains than moisture to occasion leaks, short circuits and grounds. Its effects are more lasting and less remediable than those of moisture.

The effect of heating is explained under the fault of that heading.

The Increase of Losses.—There are necessary losses in every dynamo, measured as the difference in energy between that transmitted by the engine shaft and that developed as electrical energy at the dynamo terminals; all are more or less accentuated in long service.

The bearing friction loss is kept at a minimum by oiling.

Windage is the necessary concomitant of the rotation.

Brush friction is held below an undesirable maximum by proper care of brushes and the lubrication of the commutator.

Hysteresis is reduced to a practical minimum in the design.

The C^2R losses or losses due to circulation in the current-carrying parts, and other heating losses, are treated of under Heating.

The Lost Volts.—The difference between the total electromotive force generated and the terminal voltage, or the lost energy derived therefrom which is necessary to circulate current through the armature and the series-field coils, and which may be roughly assessed as 2 to 3 per cent of the rated voltage, is a loss for a designed hot resistance of the circuits involved; this will be increased by any excess heating of these circuits and for the reason that more lost volts will be necessary to circulate current through the increased resistance which the heating occasions.

The summation of the necessary losses may be 10 per cent and more of the kilowatt output of a new dynamo, depending on its size. Increase of the losses means unnecessary expenditure of steam in the engine and coal in the boiler, and all remediable causes should be classed as faults.

Noise.—The general compactness and rigidity of the dynamo construction restrict proper noise to very few causes. A new machine may show a low frictional noise at the commutator occasioned by the fact that the mica insulations cannot be machined as smoothly as copper; but this disappears after short use and is not commonly met with especially when the commutator has been surfaced by grinding. The core teeth of slotted core machines sometimes produce a slight humming noise as they pass the poles but it is not common in modern constructions except at high speeds; it is more common in the small sizes when it exists at all.

Singing of Brushes.—This noise is the one which is oftenest noticed, and occurs generally from rough mica or a rough or dirty commutator. The nearer to the radial direction the brushes are set the more likely it is to occur under such conditions and it is therefore more common in reversing motors than in dynamos. Radial brushes give rather a squeaking noise than a hissing or singing. In many instances the hissing and singing is caused by dry, hard or gritty carbon brushes; this should be first examined for when the noise is detected; in other cases of noise at the brushes, cleaning the commutator and a little oil will stop it.

Vibration.—The bolting and assembly of a dynamo being assured, and bearings taken up, vibration is mainly a question of the sufficiency of foundations. The fault may aggravate any looseness in connections, may start bolts, may start connections at the commutator flange or for the circuits, may cause the machine to fail to generate by weakening or destroying the residual magnetism of the field coils, and may cause sparking, particularly when there are high or low bars. Vibration in a new machine may be due to an improperly balanced armature, one whose weights are not symmetrically distributed with reference to the shaft; this fault occurs from errors of construction and can be detected by resting the armature shaft on knife-edge rails and rolling the armature slowly, the heavier side will tend to turn down. In addition to the tendency to cause vibration an unbalanced armature is quite sure to prove faulty electrically.

Dynamo Faults.

As a general rule in dynamo and electrical faults it is loss of time to form sudden conclusions; the reasoning must be by a system of elimination until the actual cause for the effect is

ascertained, the elimination to be definitely determined in every case.

Prevention of well-known effects is the necessary element of care beforehand and includes such details of ordinary operation as cleanliness from dirt, copper dust, and foreign matter, about the machines; drying of oil and moisture; seeing that the dynamo is not overloaded and that voltage is not too high or too low; that oiling is properly accomplished, etc. When faults do occur, shut down the generating set, as a rule, until the fault is found and remedied.

Sparking.—The intense heat of the electric arc is the basis of results of this evil and its effects differ mainly in degree. In a new machine it is inadmissible if deleterious, a condition which is readily judged by the color of the spark emitted. It may be asserted as a general principle that a modern slotted core dynamo armature, fitted with carbon brushes, should show no sparking whatever from no load to 50 per cent overload, whether changes of load be made in one or several steps. The neutral line, the diameter equidistant between the magnetic pole centers, and the line of commutation, the diameter passing through the brushes when under load, may not correspond, but when the brush lead is once ascertained by trial, a new machine should require but little if any adjustment of brush lead thereafter for any stage of load.

Sparking is at once a troublesome and serious fault, causing heating, fusion, pitting, and scoring of the commutator at the brush contacts irregular and vibrating contacts are then set up which quickly aggravate the condition. The following are the principle causes and their remedies: those due to errors of design or of operation before delivery, should occasion the prompt rejection of a new machine.

The following causes of sparking are met with in ordinary service operation:

1. *Brushes Not Set at Best Point of Commutation.*—This is common with copper brushes on putting on or taking off load. Move the rocker arm slowly back and forth, and nearer to the edge of the leading pole pieces, until the sparking is arrested and the line of commutation ascertained; mark it with a chisel on the frame if for carbon brushes; a good machine with carbon brushes will develop a large non-sparking arc. Particular care should be taken that the point selected is that for least heating as well,

as there may be considerable heating and yet insufficient to cause an objectionable amount of sparking.

2. *Brushes Not Making Complete Contact.*—The fault will most frequently occur with an improperly trimmed brush, that is, one which is not making contact over its entire contact surface and this will create a similar condition to that mentioned in (1) above. Poor contact may be occasioned by the fact that the brush-holder will not turn or does not work freely (see also broken coils, end).

The best method of trimming or dressing carbon brushes is to fit a close, cotton band, ends sewed, around the commutator; to this band is glued a continuous layer of fine sandpaper, its edges close fitting; the brushes are then set on the sandpaper at running pressure and the armature slowly turned under power until all brushes are evenly trimmed. **Never use emery.** When the cotton band is removed all the loose particles of sand must be carefully cleaned off, the brushes aligned in the stud, and the springs adjusted to the designed pressure; too great pressure will unduly heat the commutator surface by friction.

3. *Brushes Not in Line.*—If the brush-holder design prevents a good alignment of the trailing edges of the brushes on the same commutator bar, for the same stud, the holders should be rejected. When occurring in service the brushes should be realigned at once. The design contemplates that the brushes shall span a fixed proportion of the commutator surface and this should be adhered to.

4. *Excessive Current in the Armature Due to Overload.*—This is not usual in acceptance tests, but may result from error in throwing the load switches, from a ground or leak in the connections, and from excessive voltage; these are to be ascertained and corrected. It may occur from several causes in service: *First,* from switching on load in the external circuit which is above the rated load of the dynamo; this should never be done, except in emergency. *Second,* from a short circuit, leak, or ground; good management imperatively requires that leaks, short circuits, and grounds shall be promptly sought out and the circuits and dynamo be kept free of them at all times. *Third,* from excessive voltage; this is a matter of attention throughout a watch and is controlled by adjusting the shunt rheostat to maintain the proper field.

5. *Commutator Out of Round, Rough, or Scored.*—A commu-

tator which is eccentric is detected by gauging when revolving; or by sighting under the brushes, when they can be seen to lift; or by the chattering of the brushes; or by noting the rise and fall of the brushes by touch of the hand. The fault is one of construction and, as turning down the commutator is the only remedy, it cannot be tolerated in a new machine because all possible latitude for turning down must be reserved for other future requirements.

A rough, scored, or pitted commutator, of which an irregular worn or furrowed commutator is the aggravated case, occasions sparking from irregularity of the brush contact and the spaces afforded to be arced over.

All causes are remedied by either smoothing or turning down the commutator accordingly as the damage is small or great.

Smoothing down is done by sandpaper (never emery) held to the commutator by wooden blocks. A convenient device consists of a two-handled composition frame across which is spread a sheet of flexible brass. The sandpaper can be stretched under this sheet and be held by clamps. Screws adjust the device for differences in diameter of commutator. The advantage of the device is its convenience of application and the regularity of its action on the commutator surface.

When mere smoothing will not answer, or the smoothing will not produce a cylindrical surface, the commutator must be turned down. It is to be preferably done in a lathe but may be done with the armature in place by taking off the rocker from its collar at the outer bearing and securing in its place a special slide rest, or by clamping the slide rest to the pillow block. Turning down is a delicate operation and requires a skillful hand; a slight slipping of the tool can score the commutator irremediably. A diamond-pointed tool must be used and the turning down be done by very fine cuts or the mica will sliver. The finish is made by sandpaper or a very smooth file; grinding by hand with a stone is preferable as the mica finish is better. After finishing, the copper dust must be carefully cleaned from the bars and mica insulations.

6. *Ground in Armature.*—The cause may be due to accident to the machine by which the armature conductor has been grounded to the core. Defective, damp, or impaired insulation will cause it, and as it is a similar case to a short circuit the through con-

nection must be due to some other ground to complete the circuit. The fault is detected by test for insulation resistance.

7. *Weak Field.*—The occasion of weak field may be that a short circuit may exist between the series and shunt; or either, or both are grounded. A ground will be developed by a test for insulation resistance. In the case of opposed fields the readiest method is to test the magnetic balance, but the first indication will usually be low voltage. The distinguishing effect of sparking from weak field is that the point of least or no sparking is shifted importantly from the usual point of commutation for the particular stage of load.

The following causes of sparking are not so common in ordinary operation but may occur:

8. *Short-Circuited, Cross-Connected, or Reversed Coil in Armature.*—This fault has the distinct symptom that the affected coil is heated more than the other coils. The sparking is periodic and the coil is likely to smoke or to burn out if the set is not shut down. If no short-circuiting foreign matter can be found or the insulation of the commutator is not bridged, the cause is attributable to a ground or a breakdown in the insulation and each coil should be tested out separately. The fault is often more conveniently detected by holding a file or tool between a pair of poles; a decided drag will be felt as the broken coil passes. This should be done cautiously and with a care that the tool is not dragged into the armature and out of hand. If the coil insulation is burnt, rewinding is necessary.

9. *Broken Coil in the Armature.*—This causes violent sparking from the high self-induction set up every time the broken coil passes under a brush, the circuit being abruptly closed and broken. An exactly similar result is produced if the break be not in the coil itself but at the point of connection of the armature coil to the lugs of the commutator bars, and is the more frequent as compared with a broken coil. In either case the commutator bars will probably be badly cut or burnt but no particular coil will be heated more than another, the flashing will be bad even when turning slowly. The fault can be distinguished from that of a high bar, or poor contact, or eccentricity by slowly turning the armature when flashing will immediately ensue if the circuit is broken, but will not in the other cases unless extreme and when the fault could be detected by the hand or even seen.

An emergency remedy is to solder together the ends of the contiguous connecting commutator bars but this should never be resorted to if it can be avoided, and in any event short-circuiting of other coils must be carefully avoided and seen to. A second remedy, and more advisable in emergency, is to echelon the brushes along the stud to short-circuit more bars at the point of commutation; it is apt to cause continued sparking and the basis of judgment must be whether that sparking is deleterious. The real remedy is to wind in a new coil. The eccentricity of rotation in practice may be due to a looseness of the shaft in its bearings, or the shaft may be down, or the armature may be pulled over by magnetic drag. Any lack of alignment in bearings or looseness of shaft should be first examined into.

A very bad contact can cause similar effects and symptoms to those of a broken coil and should be taken into the considerations of examination.

10. *One or More High, Low, or Flat Bars in the Commutator.* —This case is similar to a scored or furrowed commutator and occurs from a bar being higher or lower than others or worn flat on top. It occasions sparking from the effects of vibrating the brush off contact. A similar effect may be caused if the spring tension of the brush-holder is insufficient. For the actual case of low, high, or flat bar the remedy is to turn down the commutator.

11. *Unequal Distribution of Magnetism.*—The sparking from lack of magnetic balance is remedied, if it can be, by first spacing the brushes equally around the commutator and then shifting the field frame until the voltage between successive brushes does not differ more than one volt (see Inspection of Generating Sets).

The distinctive feature of this variety of sparking is that, with well-assured contact, there is a marked difference in the amount of sparking at the several brushes. Armatures fitted with equalizing rings are likely to be free from this effect.

12. *The "Flying Break or Cross."*—This term is applied to a broken coil or connection, or a loose connection, which breaks the circuit only when the armature is in rotation, the break being completed under the action of centrifugal force or vibration, but showing a continuous circuit when tested when the machine is at rest. It is a particular case of broken circuit which has the effect of flashing rather than sparking.

13. *Insufficient Carrying Capacity of Brushes.*—This error of

design will cause carbon brushes to heat, lower their resistance by the peculiar action of carbon under such conditions, and permit of increase of current in the short-circuiting coils. The brush area of contact should be designed for a minimum of one square inch for every 30 amperes of current.

Heating.—The heating of any part of a dynamo is always the occasion of increased losses in the machine, and as the heating tends to raise the resistance of all of the circuits, which in turn increases the heating, the cumulative result becomes important.

One of the causes of heating is the friction of the brushes on the commutator which, with present designs of spring pressure in order to get close contact, is likely to cause considerable necessary heating. There is no objection to using a little vaseline on the surface of the commutator, but it must be handled sparingly. Oil, as much as can be taken from the end of the shaft and applied by the end of the finger, will answer, but it must be borne in mind that carbon brushes are very porous and will take up the oil and increase their resistance.

The heating in any electrical circuit is equal to C^2R, and it is established that any temperature higher than 200° F. affects the insulations; it is probable that 190° F. is a high limit. As a test, the heating is considered to be safe if it is not uncomfortable to the hand for a few seconds; the test should be preferably made with the back of the hand than with the palm. *Bare metal feels hotter than other substances* but even then the criterion of comfortable temperature to the hand should obtain. If the heating produces odor or smoke, the safe limit has been exceeded, and requires that the machine should be quickly shut down if the load cannot be reduced. Ordinarily it is better to shut down for the reason that under these circumstances the location of the heating can be more readily determined. Since the heat may be conducted or diffused from its original source, if the machine is shut down and allowed to cool and then started up again with full field, that part which is the source of the heating will heat first and before any effect by conduction can occur.

Water and ice are never used for cooling any electrical machinery; air and ventilation is all that can be resorted to.

Heating of Commutator and Brush Gear.—This normally occurs from friction and will occur from sparking. Arcing across the mica is a serious case; if the burnt spots cannot be removed

a new commutator will be required as there is no other remedy. Heating will also occur from bad connections in the brush-holder and the dynamo leads, and is to be distinguished by the fact that the holder and cable feel hotter; the resistance of the circuit will test high. The remedy is to improve the connections.

Heating of Brushes.—Brushes in extreme cases will glow, ordinarily they will feel very hot; it is often the case that the brushes are too small, that is, have not sufficient carrying capacity for the use; sparking may ensue. The proper remedy is to put in larger brushes and to lower the brush-holder, if possible, so that the distance through which the current must pass in the carbon of the brush-holder will be materially shortened, due regard being had to safe clearance from the commutator.

Heating of the Armature.—This may occur from overload, the condition obtaining when the machine does not spark but is on the point of sparking and is similar to the case causing sparking.

Short-circuited coils or broken connections at the commutator will heat the commutator.

Heating when due to steam or moisture will either show or the armature will feel moist. This condition is really a short circuit, and will show a low insulation resistance on test. There are two methods of remedying it. One is to place the armature in an oven at a low temperature (not to exceed 140° F.) and dry it out; on board ship a warm, dry, well-ventilated location will answer. A second method is to run about half-load current through the armature from another generator; this is attended with considerable danger if the voltages are not regular, and should not be attempted by any one except experts. In this method the armature should be turned slowly by hand or the shellac and varnish may run to the lower part of the armature. If the moisture is small the armature will dry itself if run on light load.

Foucault Currents in the Armature Core.—The core will feel hot and the armature will require greater than usual power to run it with a full field and no load. The power is to be determined by taking cards from the engine and comparing with those of ordinary operation at no load. The matter is usually taken care of in design by laminating the core, insulating the discs from each other by japan, and the avoidance of through b
the vicinity of the slots.

Eddy Currents in Armature Conductors.—The heating is due generally to the fact that the electromotive force is generated in one side of the armature before the other, and is overcome by laminating the conductors and sinking them deeper in the slots. The eddy current is more frequent with bars than with wires.

Reversed Armature Coils.—This is usually indicated by excessive current when running free though no particular coil is heated. It can only be detected by taking current from another machine and testing the deflection of a detector needle over the bars as the armature is revolved. The reversed coil will show a decided deflection of the needle as it passes. The remedy is to reconnect.

The "Flying Break or Cross."—The case is similar to that described under sparking.

Heating of Field Magnets.—This is usually due to excessive field current and is detected by the temperature of the coils. The remedy is to either decrease the voltage by rheostat or, if possible, to put in more wire, or to put resistance in series with the coil. The heating may be occasioned by a short circuit or ground. One coil will appear hotter than the others; the short circuit is not, however, in the hot coil, but in the other coils, for the reason that these coils, being short-circuited, are not receiving their proper proportion of the current, and the brunt is being thrown upon the coil which is heated. The remedy is to trace out the short circuit in the coils by test, and correct.

Field magnet pole pieces and cores will also be heated if their construction does not provide against Foucault currents, though this matter is not always taken into account as one of importance.

Moisture in the field coils is another cause of heating of field magnets, and should be tested out in the same way as for short circuit or ground, of which it is a necessary part.

General as to Heating.—Any fault which will occasion sparking will of necessity cause heating; and heating can be regarded as a remove from sparking only in degree and to be likely to end in sparking in time, in addition to its other deleterious effects in adding to the resistance of current-carrying parts—and consequent increased losses—and the destruction of insulation.

Low Voltage.—The meaning of this term is that the voltage cannot be maintained at the rated value; it is quite distinct from failure to generate.

As shown in the explanation of the formula $E = CMR$, the

maintenance of voltage is dependent upon speed and field current; the first test under this fault is therefore for the speed by tachometer, and should the adjustments of the governor fail to bring the speed up to the rated when the generator is under full-load current, it can generally be corrected by replacing the governor spring, which may have lost its initial tension from fatigue.

The speed adjusted, the source of the fault is due to the fact that the field is being robbed of its proper amount of current; which may be tested by connecting an ammeter in the shunt-field circuit, allowance to be made for increase of total current due to shunting. The loss of current may be occasioned by any of the causes mentioned under sparking for weak field. A common cause is leakage, short circuit, or ground in the shunt rheostat, which apparatus should receive its share of attention in measurements of insulation resistance. In an obstinate case of low voltage the cause was found in a train of oil in which copper dust had collected.

Failure to Generate.—This fault is that in which the dynamo produces no voltage at all or very little voltage when at required speed and all resistance has been thrown out of the shunt rheostat by moving the lever across the arc "High or Raise." These conditions having been assured the connections of the field should be closely examined for a broken circuit, short circuit, or ground and corrected. The probable cause will then be reduced to absence of or too low value of, the residual magnetism of the field cores. This fault is frequently met with in a new machine or in one which has been for a long time idle. Separate excitation from another machine or a battery will ordinarily suffice to overcome the difficulty. In many cases short-circuiting the armature and series coils will assist by circulating a current; the *short-circuiting should always be done with fuse wire of small capacity to prevent injury to the brushes or commutator.* Frequently the difficulty can be overcome by shifting the brushes backwards, causing the armature reaction to assist the field, or by pressing down hard on the brushes. If these methods fail, the field connections should be tested out to discover a reversed current in the field which could prevent excitation and yet be insufficient to reverse the polarity. Were the polarity to be completely reversed the dynamo would generate but the electromotive force would be

oppositely and though the pilot lamp would burn the voltmeter needle, being against the stop, will not indicate until the connections are reversed.

If the dynamo lowers its voltage importantly when load is switched on, and the field rheostat cannot correct it or requires a very unusual position, it is probable that the series and shunt fields are opposed on one or more coils; the erroneous connections should be tested out and corrected. A detector needle will often indicate the reversed coil.

If the polarity of the field is reversed, as shown by the failure of the voltmeter to indicate except when its connections are reversed, the engine should be stopped and the field excited in proper direction for 5 or 10 seconds by a current from another machine.

Modern machines having field cores constructed with cast metals wholly or in part will retain residual magnetism in the cores for long periods and loss of reversal is not likely; it may happen in paralleling if the equalizer switch is not closed. In the general case a test for continuity will determine the cause and excitation by a battery or from another machine will suffice.

The Operation of Dynamos in Parallel.

The design of the present standard switchboard contemplates the use of the output of all necessary machines to the fullest extent by operating those dynamos in parallel on the load as is usual in common commercial practice. It is an axiom in modern operative practice that *there is no advantage in running several units below their rated full-load capacity when one unit can carry the load.* The converse is equally true; *units should not be overloaded when others can be paralleled on the load.*

Ten years ago the paralleling of compound generators was considered inadvisable as being fraught with danger to one or the other of the machines; compound-wound machines are run in parallel nowadays with as little concern as for the shunt-wound generator. The reason lies in the better speed regulation and field control and the use of the equalizer in later compound generators and in a better understanding of the operation of, and relations existing between, such independent machines when paralleled on the load; and incidentally to the better protective action of the circuit breaker as compared with the fuse.

The compound generator being a combination of the series-wound and shunt-wound generator obeys the laws of both in its operation; hence a clear insight into the conditions of paralleling requires a knowledge of the separate functions of each.

The *series dynamo* is rarely, if ever, operated in parallel with another machine. Limiting the conditions to the placing of two series dynamos in parallel, it may be done provided:

I. *The two machines are exactly the same.* The mechanical difference incidental to construction of two machines of same design renders this result very improbable.

II. *Both machines are carrying heavy, or near full, load.* The usual practical problem would be to parallel in the machine to assist another which is, or is about to be, overloaded.

III. *Neither, or both the machines, is likely to be subjected to light load.* Should there be any difference in field strength between the two, that which has the stronger field will gradually overcome the other and assume all the load and the weaker will race away; or should the governors regulate unequally the machine taking the higher speed (and hence voltage) would assume the load and stop (and might reverse) the other driving it then as a motor, its current becoming an extra load on the first machine.

IV. *That the machines are connected through an equalizer.* This arrangement would probably be necessary in any of the conditions in I, II, and III.

V. *The fields of the two machines are interchanged.* That is, that the circuits are so connected that each machine excites the field of the other. This arrangement has been used practically in emergency but is not considered good practice.

The resulting conclusion from the unfavorable probabilities of paralleling series-wound generators is that it is rarely attempted. The use of the series-wound dynamo is now-a-days practically confined to arc lighting.

The shunt-wound dynamo can be paralleled with other similar wound machines with ease. The method and the effect of varying voltage may be illustrated by an assumed example. A 50 k. w., 80-volt, shunt-wound generator *A* is supplying 625 amperes (full load) to the external circuit and 10 amperes to its field; the voltage at the field terminals is 70, terminal volts at switchboard 80, and effective armature resistance 0.005 ohm.

The total electromotive force which *A* is generating consists of two parts, the 80 volts shown by the switchboard voltmeter, or terminal volts, and the volts necessary to circulate 625 amperes through its armature plus the 10 amperes in its field; the latter called the "lost volts," is evidently, $635 \times 0.005 = 3.175$ volts; call these lost volts three volts.

It is now desired to increase the external load to 1200 amperes and a like machine *B* is to be paralleled with *A*.

B's engine is brought to rated speed and the voltage adjusted *not to 80 volts, but to 83 volts;* for, from the well-known shunt machine characteristic, when *B* is paralleled with *A* and assumes half the load, 312 amperes, *B's* voltage will drop to 81½ volts, while *A's* will rise to 81½ volts due to the removal of half-load. The negative pole circuit breaker, or switch for *B* is closed to the negative bus bar and then the positive side to the positive bus bar. *A* and *B* will divide the current between them (of course, within the allowance of 20 per cent), each taking 312 amperes, the voltmeters of each machine showing 81½ volts. The voltage of both is now adjusted to 80 volts and each has a load of 312 amperes. The loads are then put on until 1200 amperes is shown on the line, or 600 on the ammeters of both *A* and *B*. It makes no difference after that in so far as voltage is concerned how the load is varied, *A* and *B* will automatically divide it practically equally; all that is required is that the voltage be adjusted by the shunt rheostats to be 80 volts for each machine.

Case I.—Assume that while both *A* and *B* were running at 80 volts and 312 amperes the voltage of *A* is raised by its rheostat to 83 volts and the voltage of *B* adjusted to remain at 80 volts (or what is practically the same thing *A's* voltage is made 3 volts higher than *B's*).

Neglecting the slight effect on the field of *B*, *A* would impress on the armature terminals of *B* a voltage of 3 volts, equal to and opposite in direction to, the drop (lost volts), on the armature of *B*, and *B* can supply no current; hence *A* must assume the whole load of 625 amperes and *B*, though still in parallel with *A*, will be running under the same no-load conditions with full field as it was before being put in parallel with *A*. Were this to have happened when both were carrying a load of 600 amperes, the heavy overload would have been thrown on *A* and would probably burn out its armature; it would not have been as much as

1200 amperes, however, as *A's* engine would slow and decrease its voltage. Accident to *A's* armature would be prevented in practice by the fact that the circuit breaker would trip or the fuse blow and prevent the overload on *A*, all circuits being then deprived of energy.

Case II.—Both *A* and *B* being at 80 volts and 312 amperes *A's* voltage is raised more than 3 volts in excess of *B's*.

A not only stops all supply of current from *B* but the excess difference above 3 volts will cause a current to flow in *B's* armature, oppositely in direction from that which *B* should normally supply; *B* becomes a motor operated by *A*, and *A* now takes not only the total load of 625 amperes but also the current which it is supplying to *B*. The motor action taken by *B* will turn its armature in the same direction as before and assist the engine in handling no-load conditions, causing the governor to throttle steam; the tendency will be for *B's* armature to race also, the increased speed operating to farther assist the governor in throttling steam. When the condition obtains that the motor action has caused the governor to bring the valve to minimum travel, steam leakage will probably operate to fill the cylinders and slow *B's* engine, still more decreasing the voltage of *B* until when the voltage of *A* exceeds that of *B* by 6 volts *A* is supplying 625 amperes to the external circuit and 625 amperes to *B*. In actual practice *A's* engine would slow and its circuit breaker open before any dangerous condition of overload could exist, but these facts apart the sequence of events would probably be as given.

From these cases it is evident that the engines of *A* and *B* should so regulate, and the control of their fields be such, that their voltage difference shall be kept within at least the limits of 3 volts; and that the circuit breakers or fuses should operate with certainty at the maximum of load for which they are adjusted.

When paralleling compound dynamos the likelihood of occurrence of the difficulties advanced is materially reduced instead of enhanced as was formerly supposed; it is effected by the use of a device known as the equalizer.

The equalizer is a connection which is made from the negative (usually) pole of each dynamo to an independent bus bar, called the equalizing bus bar on the switchboard; *it is essential that the*

connection be inside the series field, that is, between the series field and the negative brush.

The primary effect of the equalizer of two compound machines is that it places their series fields in parallel, keeping both terminals at constantly equal polarity. In a case of a machine *A* running at 80 volts and 625 amperes and a machine *B* running at 80 volts (shunt field only) and no load, and the equalizing switches of both machines closed and also the negative switch of machine *B,* the current passing into the series field of *A* has two paths: *first,* through *A's* armature; *second,* to the equalizing bus bar, thence through the series field of *B,* to the negative bus bar, and back. Hence, these paths being equal in resistance, one-half of *A's* series-field current will shunt through *B's* series field (though none passes through *B's* armature) and *A's* voltmeter will show a decreased voltage (the series field having been deprived of part of its magnetic effect) and *B's* voltmeter will show an increase of voltage; these voltages having been readjusted to show 80 volts for each machine, the total field of *A* and *B* will be exactly the same as when *B* is paralleled in by closing *B's* positive switch, that is, the new adjustment with the equalizer switch has prepared the fields of both machines for the conditions which they are to have when the paralleling is completed by closing *B's* positive switch, the effect of such closing being merely to throw 312 amperes on *B's* armature and 312 amperes on that of *A;* this will be immediately apparent from a rough diagrammatic sketch.

In practice, the change of engine speed will necessitate a re-equalization of voltage after paralleling; a qualification also enters from the fact that the total armature current does not flow through the series fields, part passing through the series shunt.

Method of Paralleling in a Second Dynamo of Same Capacity as that Already Running.—From a set of careful experiments are deduced the following rules for paralleling a second machine with one already running under load.

1. *See that the voltmeter is properly connected.*

2. *Bring the dynamo up to rated speed and voltage.* The speed under the no-load conditions will be evidently a little greater than that for full load, hence the governor should be adjusted for rated speed and the voltage for full load.

3. *Adjust the voltage of the machine which is under load two (2) volts higher than that of the line (rated voltage).* This is

to compensate for the decrease in its voltage when the equalizer switch is closed.

4. *Close the negative switchboard switch of the dynamo about to be put in parallel.* There will be no change of conditions due to this operation. It is frequent in commercial practice to run the negative lead straight, that is, without a switch, but the precaution of breaking the circuit by a switch is safer practice.

In interpreting the term "negative switchboard switch" the *switch to be closed must be that on the dynamo leg which has the series field.* Generally the connection is made at the negative (return) side, but if made on the positive side the "positive switchboard switch" would first be closed. This applies to the terms negative and positive throughout these directions.

5. *Close the equalizer switch for both dynamos.* The voltage of the loaded dynamo will decrease and that of the other will increase since their series fields are in parallel. Should the effect on the voltmeter of the machine to be paralleled in show a decreased voltage, it is evidence that the machine is not poled right; this, however, can scarcely happen because when it first showed voltage due to the shunt field alone the voltmeter should not have indicated (pointer thrown against the stop); the voltmeter connections should be examined and corrected.

6. *Adjust the voltage of the loaded dynamo about one (1) volt below and that of the other dynamo about one (1) volt above the rated.* This is to adjust the voltages for the effect of the unloading of the one and the loading of the other.

7. *Close the positive switch of the dynamo which previously carried no load.* Each dynamo will now take practically half the original load.

8. *Adjust the voltages of both dynamos so that each machine takes half the load if not already so provided.* The change in engine speed and the effect of change of load will probably cause the voltages of the two dynamos to differ.

9. *Switch in the desired loads in excess of that already carried.* For each new load switched in the load should divide itself equally between the machines. If the characteristics of the two machines are widely different it may become necessary to proceed again as in 8.

To Shift the Load from one Dynamo to Another.—Proceed

exactly as in the steps 1 to 8, inclusive, for **method of paralleling in a second dynamo,** then

9. *Simultaneously raise the voltage of the new dynamo and lower that of the dynamo which has been in operation until the ammeter of the latter shows no load* and the ammeter of the former shows full load.

10. *Open the positive switch of the dynamo which is to be stopped.*

11. *Open the equalizer switch and then the negative switch of the dynamo to be stopped.*

12. *Slow and stop the engine.*

To Throw a Dynamo Out of Parallel and Stop.—Proceed exactly as in the steps 9 to 12, inclusive, for shifting the load.

Paralleling of a Dynamo with Two or More.—The particular effect in case a third, or fourth, etc., dynamo is paralleled in with two or more dynamos already paralleled on the load is in the voltage effect produced when the equalizer switch is closed and when the positive switch is closed, *and in any case the operation must be completed for each unit before its successor is paralleled.* In the case where two dynamos are already running the effect on their series fields would be to lower them but one-third each approximately, while the third generator would receive two-thirds of its series field current directly the equalizer switch is closed; if a fourth dynamo were paralleled with three others, it would receive three-fourths total field current at once, and the series fields of the other machines would decrease but one-fourth; for five machines the effect would be four-fifths and one-fifth and so on. Experience with the machines and a knowledge of their individual characteristics will govern, but usually the rule of steps 3 and 6 for paralleling in a second dynamo can be safely followed.

Cutting out a dynamo would be practically as explained for throwing a dynamo out of parallel, at the same time adjusting the rheostats of all machines remaining on the load.

Paralleling Dynamos of Different Capacities (Sizes).—The resistance of equalizer and series field in series must be such that the drop across the series field and equalizer leads will be the same for each dynamo and be inversely proportional to the capacities, otherwise the voltages will not equalize and one machine will assume more load than the other; this assured, it is better to lower the load of the larger machine until the half value will not

exceed the full-load capacity of the smaller dynamo; paralleling is then accomplished as in other cases, all increase in load being thrown on the larger machine by regulating the rheostats so that the load of the smaller may not exceed its full load.

The practice requires close attention, and is, for the general case susceptible of accident and inadvisable.

To Start a Generating Set.—Before starting the following should be carefully examined into and adjusted:

That the circuit breaker is open.

That the separator and trap connections are right.

That the working parts of the engine are well connected up and cotters in place, especially about the cross-head and crank connections.

Before putting on the cylinder heads and valve-chest cover remove any tools, chips, or dirt which may have lodged in or dropped into the cylinders, chests, or steam ports. Carefully examine the setting-up bolts and their nuts and locking nuts, noting that cotter pins are in place; all packing; bearings; oiling system and connections; oil pumps; holding-down bolts of engines, dynamo, and outer bearing. See that the strainer is on the suction of the oil pump and the rings of the ring oilers in their seats. Turn the engine slowly by hand and overlook all working parts. Fill the oil reservoir with clean (new) oil to within 2 inches of the crank when down. Do not close the doors until the engine has been seen working at one-third speed at least. In short, the smaller details of both engine and dynamo should be examined as an assurance against accident or injury.

See that the oil reservoir in the base is filled to the level mark on the gauge glass; that all grease cups are filled and the feed set up; that the reservoir of the ring oiler bearing is full to the mark on the gauge glass; that the oil-pump connections are in order and the strainer in place. (If gravity feed, see that the tank is full, or fill the oil cups, and try the drip cocks.)

Open the main valve on the main steam pipe and see that the boiler pressure and pressure on the engine line is up to normal and that the condenser is operating on the exhaust line.

1. Open all drains to cylinders, separators, and traps.

2. Turn the engine to the dead center by hand, open the engine stop valve a very little, open the throttle and by-pass valve slightly and let the engine warm up for at least 5 minutes; then

turn the engine to the other center and repeat the warming for the same length of time. (When there is but one attendant, it is better at this time to put in resistance in the shunt rheostat by moving the shunt rheostat well over on the "Lower" side in order that when the engine is started he will not have the engine and voltage to take care of at the same time.)

3. Open the main exhaust valve (on the main line).

4. Close the throttle valve.

5. Open the engine stop valve.

6. Open the throttle again gradually until the engine, started with the starting bar, works at low speed and keep it at this speed until all water is worked out of the cylinders as noted by the water hammer. A piston rod or piston may be broken or injured by starting the engine should there be any water in the cylinders.

7. Close the drain valves and open the engine exhaust valve. When other engines are running and exhausting into the same main exhaust pipe, closing the drains and opening the engine exhaust must be done coincidentally that the vacuum may not be too greatly affected; were the exhaust valve well open before the drains are closed the condenser would be open to the atmosphere.

8. Open the throttle gradually until wide open. Always run an engine with a wide open throttle and let the governor take care of the steam supply.

While the engine is turning over the dynamo is taken in hand and it is necessary to see:

That the circuit and main fuses are in good order and well secured.

That the dynamo connections, and to switchboard are intact.

That the brushes are properly trimmed and aligned. That the generator is not damp, or dirty, or spotted, or streaked with oil.

If the generator is provided with copper brushes, the brushes should be off the commutator before starting and not let down until the armature is at speed. Carbon brushes should be let down on the commutator before the engine moves; with copper brushes, however, the engine should be first slowly moving, otherwise should the engine reverse when first turning over, due to back pressure or error in handling the starting bar, the brushes and holders may be injured.

9. As the generator comes up to voltage adjust the shunt

rheostat to bring to the rated voltage as indicated by the pilot lamp.

10. Close the circuit breaker (or main switch) and adjust the voltage shown on the voltmeter by the shunt rheostat.

11. Throw on load gradually by closing the circuit switches, keeping up the voltage by the shunt rheostat, until all the desired load is on.

Copper brushes must be shifted in the direction of the armature rotation, as the load is put on, as may be necessary to avoid sparking.

The dynamo-room circuit is usually switched in first to light up as soon as practicable.

To Stop a Generating Set.

In the usual ship case one set is shut down when another is started; hence:

1. Throw the load gradually from the set to be stopped by regulating the voltage by the shunt rheostat, until all load has been shifted to the other set.
2. Open the circuit breaker (or main switch).
3. Close the throttle about half way.
4. Close the exhaust valve first and then open the drain valves.
5. Close the throttle.
6. Close the engine stop valve.

The exhaust must be closed before the drains are opened or the condenser will be open to the atmosphere.

In testing, the throttle is usually gradually closed without breaking the load, thereby keeping up the pressure in the cylinders to clear out water.

The load should always be broken in steps. For testing the governor (engine regulation) it is permissible to break the load from full load to no load and the reverse, but such strains on the governor and working parts should be limited to test only; the occasions when, from the blowing of the fuse or opening of a circuit breaker, the actual sudden loads occur are those for which the test is intended to demonstrate a preparedness.

If the dynamo is fitted with copper brushes they should be raised from the commutator as soon as the engine has stopped.

Laying Up a Generating Set.

When the engine is not to be run again for a week or more, the cylinder heads and valve chest covers should be removed and the cylinder and valve-chest walls coated with a thick layer of vaseline to prevent the piston and valve from freezing (rusting) to the walls.

Should it be the expectation that the generating set will not be run for two or three months, or in the case of a ship going out of commission, remove cylinder heads, valve-chest covers, and all soft and metallic packing; take out the pistons and the valves (marking the setting on the stem), put a thick coating of cylinder oil on the cylinder and valve-chest walls and put back the pistons and valves; put the cylinder heads and valve-chest covers on and set up loosely, allowing the air to circulate and any condensation to escape or evaporate; coat all bright surfaces thickly with cylinder oil, including valves and valve stems, pistons and piston rods, and the piston rings. *If the generating sets are to be shipped to a distance,* white lead and tallow will last better than cylinder oil. Both metallic and soft packing have been found to have rusted a piston rod for a depth of 1/32 inch after one month, and the packing should be removed if the engine is to be laid up or shipped.

The Motor.

Dynamos and motors are so similar in their construction, and one machine can be so generally used for the purposes of the other, the difference being mainly in the adaptability for a specific use, that they have much in common and especially as to faults.

The chief accident to shunt motors is the burning out of the armature or field coils from overload in the circuit. The methods of avoiding it are:

1. A careful elimination of leaks, short circuits, or grounds.
2. The use of a circuit-breaking device which will operate either *on overload or on failure of the line voltage.*

Overloading requires no further explanation than that the excessive current heats and chars the insulations.

Burning out from failure of the line voltage occurs in this way: the starting rheostat resistance is tapped at a series of points or blocks. In starting, the rheostat lever, which is connected to one terminal of the supply circuit, is moved slowly from point to

point, or block to block, gradually decreasing the resistance in circuit, permitting more voltage on the armature of the motor, until the lever gets to the last block, when all the resistance due to the rheostat is cut out and the current leads directly through the lever to the armature, giving it the total voltage of the main line. There is usually a switch in the circuit. If a break in the main line occurs, thus shutting off the motor supply, the rheostat lever should be immediately placed on the "off" block, where it was before starting; otherwise, when the supply is renewed, the motor suddenly receives the full voltage of the line before it has had an opportunity to start, receives an overload, as no back electromotive force is being generated, and the armature is burned out.

Back electromotive force is readily understood from a brief explanation. Inasmuch as the armature of the motor revolves in a magnetic field, it becomes a dynamo to the extent of the number of its coils, the intensity of its field, and the number of revolutions $(E = CMR)$, and of its own accord generates an electromotive force opposing that coming from the line; the current to be carried by the armature is by design based on the difference between that of the supply line and the back electromotive force generated by the motor, and an armature burns out when suddenly subjected to the full electromotive force of the main line for the reason that its winding was not designed to carry such high currents as will flow.

In most cases of burnt-out armatures which have been investigated it has been found that the rheostat lever was left on the full-voltage block ("armature stop").

The burning out of the starting rheostat occurs almost invariably from attempts to use it as a speed regulator. The resistance wires are designed to be subjected only to heating effects for the short time necessary in starting, and it follows that if the lever is permitted to remain on any block intermediate between the first and last, the resistance wires will gradually overheat and finally burn out. When speed regulation is desired a controller of special design whose resistances are designed to stand the necessary heating should be employed.

Faults.—The causes of faults in a motor are similar to those of a dynamo and are similarly remedied.

CHAPTER XIII.

ELECTRIC FIXTURES AND LANTERNS.

The regular fixtures and lanterns are those used for lighting various compartments and spaces on board ship and include the following:

Fixtures.

Ceiling fixtures, Nos. 1 and 3.
Ceiling fixtures, Commercial.
Bracket fixture, single.
Bracket fixture, double.
Overhead bunker fixture.
Drop fixture.
Deck fixture.
Bulkhead fixture.
Bunker fixture.
Electrolier.

Lanterns.

Deck lantern.
Battle lantern.
Cargo reflector.
Desk light.
Portable N. W. T. and W. T.
Magazine lantern.

The special fixtures and lanterns are those used each for some specific purpose other than mere illumination of spaces on board ship and include the following:

Masthead lantern.
Top light.
Towing light.
Range light.
Diving lantern.
Binnacle light.
Telegraph fixture.
Stern light fixture.
Five light reflector.
Night signal lantern.
Side light, red and green.
Side light, red.
Signal lantern, green, red and white.
Peak light.
Truck light.
Turret hood fixture.
Semaphore, wigwag.

The torpedo-boat fixtures and lanterns are those used only for torpedo-boats and destroyers, and for special uses and include the following:

Masthead lantern.
Signal lantern, green, red, and white.
Binnacle light.
Wigwag signal.
Side light, red and green.
Truck light.
Magazine light fixture.
Night signal set, 2-light.

Ceiling Fixtures.—The former types and as sometimes still met with are four in number and designated as Nos. 1, 2, and 3, and commercial.

The No. 3 is the same as the No. 2, excepting that the No. 3 has a band of open filigree work placed above the plain ring of the No. 2; the former No. 3 fixture has been discarded, and a new No. 2 designed to replace the former No. 2.

The present standard No. 1 and No. 3 have been designed with reference to use with both conduit and molding, doing away with the wooden blocks that were necessary for securing the former varieties.

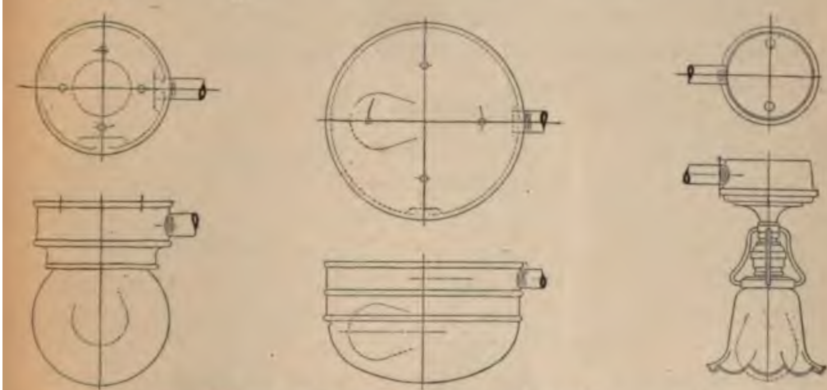


FIG. 240.—From left to right; ceiling fixtures No. 1, No. 3, and commercial.

Ceiling Fixture No. 1.—The fixture with its globe, is as shown in Fig. 240.

It consists of a brass casting one part of whose side walls is thickened to ⅝ inch, forming an interior boss for the tap hole for the conduit. Two similar bosses are cast on the side walls 90 degrees from the conduit entrance: one, as may be most convenient for the particular run, is tapped for the conduit for the switch wires to avoid a T on the outer conduit line leading to the fixture. The fixture is secured in place by four screws through the bottom of the base. The globe ring is in one with and smaller than the base; it is internally threaded to take the threads of the globe.

The globes are usually frosted; the frosting should be done on the inside surface of the globe, the outside being perfectly smooth; if frosted outside the collected dirt interferes with the illumination

and the globe is difficult to clean. The type-A socket is used, which is cushioned against shock by interposing a packing, or gasket of 2-ply cotton-insertion sheet-rubber packing between the bottom of the casting and the porcelain. A similar gasket fits under the edge of the spherical globe and packs the fitting water-tight. The entire inside of the base is painted with white enamel. Ceiling fixtures No. 1 are usually finished in bronze.

Ceiling Fixture No. 3.—The fixture with its globe is shown in Fig. 240.

It consists of a brass casting, one part of whose side walls is thickened to ⅝ inch, forming an interior boss for the tap hole for the conduit. Four screws through the bottom secure it in place. The fixture switch is provided for by using a branch box on the

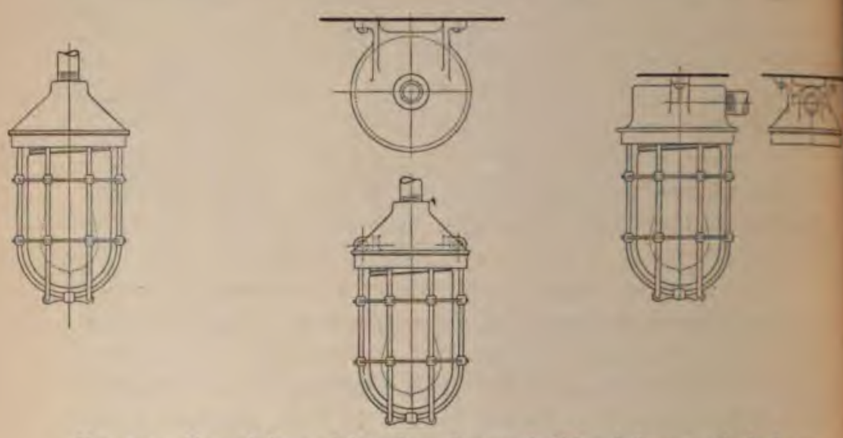


FIG. 241.—From left to right; drop fixture, bulkhead fixture, deck fixture.

conduit line. The globe ring is in one width, of the same diameter as the base, and is internally threaded to take the thread of the globe. The socket used is the standard metal type which screws on an arm attached to the base, the arm being perforated for the passage of the wire to the socket contacts.

The globe is packed water-tight by screwing against 2-ply cloth-insertion sheet-rubber packing ring. Globes for this fixture are of clear glass, except when used in quarters. When frosted, the frosting should be on the inside.

The interior of the base is painted with white enamel, especially the inside of the bottom of the base which acts as a good reflector.

Ceiling fixture No. 3 is much more efficient for overhead lighting than No. 1, as the best effect of the lamp is utilized in the flat position and the reflector economizes the lost rays.

Drop Light, Deck Fixture, Bulkhead Fixture.—The three types are colloquially known as the steam-tight fixture. The primary idea of the design of this line of fixtures is to obtain a similar construction for all, whose guard will be safe against the deformation and destruction incident and common to the weak flat wire guard heretofore in use, and to combine in three types all necessary to the various uses.

The difference between the three exist only in the base, the remaining parts being the same for all.

The drop fixture base (Fig. 241) is tapped for a central boss, the conduit acting as the support or pendant; no securing lugs are necessary as the fixture is to be set flying. It replaces the old type of steam-tight fixture, and its convenience in high fire-rooms where it can be run down for overhead lighting or for lighting instruments and gauge glasses will at once be recognized.

The deck fixture base (Fig. 241) has a boss all the way across the top; one side to be tapped for the wires leading to the lamp; the other for the switch wires when the switch is to be installed on the opposite side of the light, a convenient method.

It is designed to replace the former type of steam-tight fixture also, and to be used instead of the drop fixture where it is desirable and necessary to use all available height overhead; or where a conduit lead comes from the side; or where it is desirable to bring in the conduit at the side rather than make the bend necessary for the drop fixture (bends increase the difficulty of drawing wires). This fixture is used preferably for overhead lighting of berth decks, passages, under fire-room and engine-room gratings, etc. (provided there is sufficient head room as the fixture extends below the beams), giving good dispersion and rendering fewer lights necessary.

The bulkhead fixture base (Fig. 241) has its boss at the top and the lugs are placed at the side. This arrangement of the lugs permits installing the fixture against a flat surface. It replaces the former type of bulkhead fixture for side lighting of berth decks; for reading lights for the crew; for lighting the decks under the hammocks after overhead lights (which would shine in the eyes of the occupants of the hammocks) are extinguished; for

side lighting of engine and fire-rooms and about auxiliary machinery; for lighting spar decks; for overhead lighting when the head room is not sufficient for the deck fixture; and for overhead lighting in many spaces where the ceiling fixture No. 2 has heretofore been used.

As the beams interfere with the dispersion of light from a bulkhead fixture more of them are required for overhead lighting of a space that would suffice for the deck fixture; they are not used if sufficient head room for the deck fixture is available, handling gun gear, etc., being taken into consideration. Their use in a horizontal position is, however, often open to objection, as there is a liability of water entering the interior of the globes if not kept screwed tight.

The base is a conical shaped, hollow, brass casting, having an internal flange and rib; a type-A socket secures by two screws to the rib, and on ring and flange is placed a wide ring of 2-ply cloth-insertion sheet-rubber packing which forms a cushion for the socket and a gasket to water-tight the globe.

The guard is made of four 3/16-inch brass wires which are bent to shape and inserted at the top through the four arms of a brass (cast) guard flange. The guard is threaded internally to screw to the outside of the threaded collar and is cast with lightening recesses between the solid web through which the holes for the wire of the guard are threaded. The wire is soldered where it passes through the guard rings. The base is internally threaded for the thread of the glass globe.

The globe is made of clear flint glass 6 11/16 inches long; a variation of 1/16 inch, either way of this dimension is allowed.

The interior of the base is painted with an insulating varnish. The guard is finished in dark bronze and the outside of the base is painted to correspond with that of the compartment; if white, the paint should be enamel paint.

The Bracket Fixture.—*The single bracket type* is shown in Fig. 242. The arms are curved brass tubes into which is screwed a shouldered-shaped nipple, threaded for securing a standard metal socket. The other end of the tube is brazed into a filleted, cast brass, conical section, drilled for four screws which secure it to the base.

The base is a brass casting having a boss cast in the side walls for the conduit, and two smaller bosses, either of which can be

tapped for the conduit of the switch wires. Cast with the base are four bosses which are tapped for the screws holding the cast brass section. A collar carrying the shade holder slips over the outer threaded end and is held by the socket; three thumb screws on the rim of the shade holder hold the shade in place. The shade is of the fluted pattern.

The double bracket type (Fig. 242) is a modification of the single bracket for two lights, the arms being set out at an angle from the crown of the base.

All bracket fixtures are finished in dark bronze.

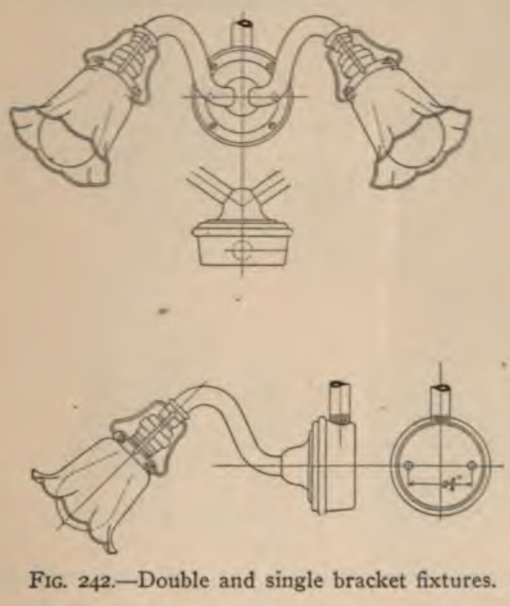


FIG. 242.—Double and single bracket fixtures.

The commercial ceiling fixture (Fig. 240) is a modification for overhead lighting of the single bracket fixture construction and is used to replace ceiling fixture No. 1 in various locations.

The Electrolier.—This is a modification of the commercial ceiling fixture in which two, three, or four arms of the bracket fixture are attached to the crown of the base for two, three, or four lights. But one tap is made for the conduit.

The Bunker Fixture.—This type of fixture is shown in Fig. 243. The fixture consists of a cylindrical brass casting, to which a removable cover is attached by four stud bolts, the joint being

packed by a 2-ply cloth-insertion sheet-rubber packing. The cover has cast ribs for stiffening. On the back of the cover is a screw cap, also packed water-tight at the joint; this cap can be unscrewed for examination of the condition of the lamp and the glass base.

Cast in one with the cylindrical casting is a flange which is gusseted to the main casting for strength; this flange is drilled for twelve ⅜-inch by ⅞-inch bolts which secure it to the bunker bulkhead, the flange being set back sufficiently on the cylindrical casting to allow its face to project beyond the inside (bunker side) of the bulkhead.

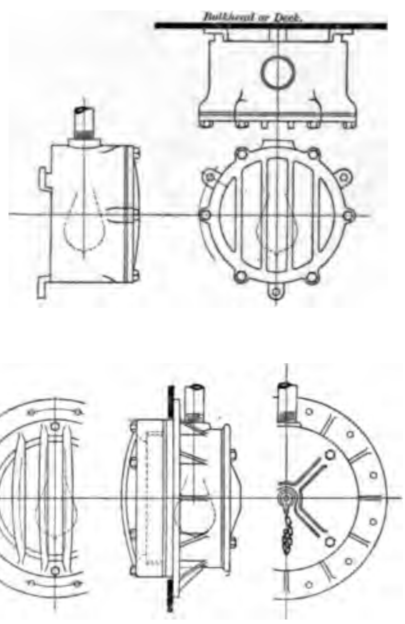


FIG. 243.—Overhead bunker fixture (top) and bunker fixture.

On the bunker side the fixture has a follower ring, across whose face are cast four strong vertical guard ribs, to protect the glass face; these are disposed radially on the horizontal axis to lessen obstruction of the light. A glass disc, similar to a deck light and one inch thick is inserted between the outer flange of the follower ring and the face of the cylindrical casting and made water-tight by sheet-rubber packing rings front and back. A type-A socket is used, cushioned by a packing ring, and secured on the top of the boss which is tapped for the conduit.

Overhead Bunker Fixture.—The design of the preceding bunker fixture is such that it cannot be installed overhead where it could light the bunker more efficiently; for this purpose the overhead bunker fixture (Fig. 243) is used, though difficulty of access prevents the general use of a fixture of this type where the face must be taken off to obtain access to the lamp for renewal. The overhead bunker fixture is only used for the overhead lighting of bunkers; its interior is painted with white enamel.

Deck Lantern.—The deck lantern (Fig. 244) is a battle lantern without a shade and shutter. The top is a brass casting having a boss and stuffing tube, taking a D-13 gasket. Two cast lugs on

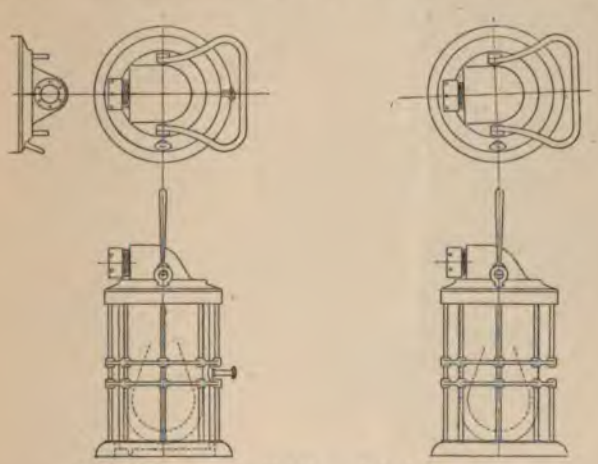


FIG. 244.—Battle (left) and deck lantern.

the top secures the bail. Against the inner face of the top is secured a type-A socket. The inner side of the side flange is thread for a globe of the same type as used in the steam-tight fixture.

The guard consists of a ring screwing on the outside edge of the flange of the top to which are riveted the rods made of brass wire, 3⁄16-inch diameter. These rods pass through two guard rings, to which they are soldered, and their ends are riveted to the base ring, which is about one inch wide; the bottom of the lantern is thus open permitting the light to shine down as well as through the side of the globe.

The lantern is for ordinary use about decks as a hand lantern.

It is wired up with double conductor, plain, wire and finished with the standard water-tight attachment plug.

One-half of the number of deck lanterns allowed a vessel have a length of conductor of 25 feet, one-fourth, a length of 50 feet, and the remaining one-fourth, 100 feet.

The fixture is finished in dark bronze.

Battle Lantern (Fig. 244).—The battle lantern is a lantern adapted for use around guns, etc., in night action.

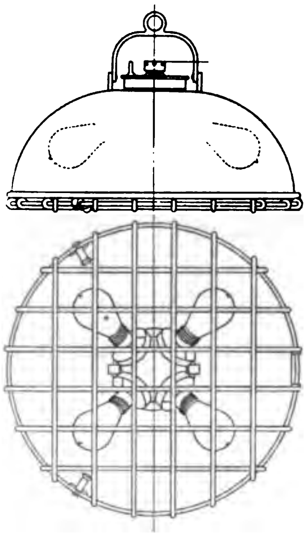


FIG. 245.—Cargo reflector.

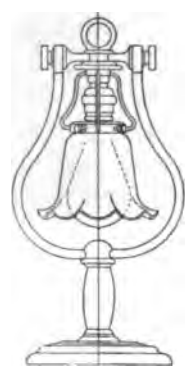


FIG. 246.—Desk light.

Within the guard of the battle lantern, for one-half the circumference and for the total length of the lantern, is rigidly secured a brass shade shutting off all light for that section; for the remainder of the circumference is a similar sheet of brass, acting as shutter by sliding in guides, and controlled by a knob extending out between the guard rings. All side light can, therefore, be cut off at will, or half the side light is utilized as desired. The bottom lighting can also be controlled by a hinged shutter which closes up against the base ring. Its remaining construction is the same as that of the deck lantern.

This type of lantern is wired up with double conductor, plain, and finished with a water-tight attachment plug; the length of

wire is that best adapted to the locality of the particular gun. The finish is dark bronze.

Cargo Reflector.—The cargo reflector (Fig. 245) consists of a dome-shaped reflector of spun brass whose edge is wired. A wire guard made of a mesh of 12 round brass wires, tied, or clipped, and soldered at the cross, hinges to the edge, and is secured by two spring latches at 135 degrees from the hinge center. The dome is riveted and soldered to a top casting which is tapped and threaded for four type-A sockets, the sockets setting at about 45 degrees wth the vertical. A cast cap is fitted centrally with a stuffing tube and gland, the tube taking a D-13 gasket for packing the single, double conductor, plain, wire used. Secured to the top casting are two lugs on which the bail hinges. The interior of the dome of the reflector is painted with white enamel. The outside is in dark bronze.

Four 16 candle-power lamps are used in this fixture; each socket is first wired separately with double conductor plain, the ends are soldered in parallel, and to these are soldered the double conductor plain, of the fixture conductor, all joints being well taped. The conductor is 100 feet in length and finished with a water-tight attachment plug.

This type of fixture is used for lighting gangways, over coal barges, lighters, etc., when working at night and an especial amount of illumination is required, and for illuminating holds and hatches in handling cargo.

Desk Light.—This fixture (Fig. 246) consists of a heavy base into which is screwed a fluted handle to which is screwed a knob. Into this knob are screwed the two pedestal arms; the upper ends of the arms are bored for the ends of the cross bar which is fitted with clamping nuts. All joints are brazed.

The lamp holder fits through the central ring of the cross bar and is detachable. It consists of a brass casting into which is screwed a ring for hanging up the lamp on cup hooks when off the pedestal. The lamp can be swung from side to side when on the pedestal and clamped at an angle, however it may be suspended. The socket is of the standard metal type and clamps the shade holder whose ring has three thumb screws securing the shade. These shades are the same as those used for the bracket fixture.

The fixture is connected to a length of double conductor, silk,

not less than 15 feet in length and finished off with a non-water-tight attachment plug. It is usually finished in bronze.

The Portable.—*The non-water-tight portable* is shown in Fig. 247.

A brass tube is inserted in a wooden handle. The outer end of a second tube is coned for a D-13 gasket and fitted with a gland. Around the inner end is a base ring, perforated with ten ½-inch lightening holes and secured to the first tube by two clamping rings set up against sheet-rubber packing rings, one ring packing the interval between the base ring and the tube. The end of the

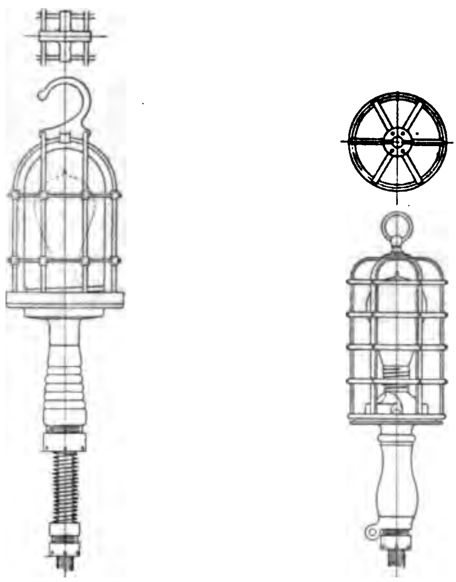


FIG. 247.—The water-tight (left) and non-water-tight portable.

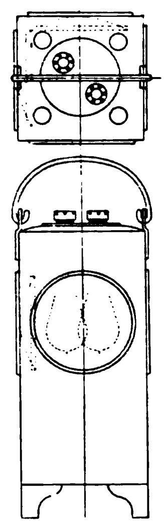


FIG. 248.—Magazine lantern.

first tube is threaded to take the standard metal socket. The guard is made of light flat brass wire with six guard rings riveted to the four upright flat wires. The top is finished off with a knob casting and ring to which the upright wires are riveted. The base of the guard is a cast ring to which the upright wires are also riveted, and which is threaded on the inside to take a similar thread on the flange of the base ring.

The portable is wired with double conductor, plain, wire; one-half the allowance to a ship has a 25-foot conductor, one-fourth a

50-foot and one-fourth a 100-foot. The attachment plug is of the water-tight type.

The portable is finished in dark bronze.

It is intended as a non-water-tight, light type for usual and convenient service about ship locations where it is not likely to meet with rough usage or dampness.

The water-tight portable (Fig. 247) is made up in the same general style as the steam-tight fixture, the construction answering for both except in the following parts.

Cast with a cross is a brass hok for hanging the portable. The base consists of a brass tube around which is worked a fluted wooden handle; the outer end of the brass tube being fitted with a gland which sets up on a D-13 gasket around the double conductor, plain, wire used for the fixture. Brazed to the outer end of the brass tube is a phosphor bronze spring ending in a brass casting which is fitted with a gland for a D-13 gasket; this is similar to, and for the same purpose as, that of the non-water-tight portable.

This portable is intended to be used in double bottoms, engine, and fire-rooms, damp locations, or where a portable is to be subjected to hard usage; and it is made water-tight. Being furnished with a glass globe and a heavy guard it is too heavy a fixture for ordinary use, and the lighter type before described is supplied for the ordinary occasions of portable use.

One-half the allowance is wired with a 25-foot conductor, one-fourth with a 50-foot, and one-fourth with a 100-foot, the water-tight attachment plug being used. The finish is in dark bronze.

Magazine Lantern.—The lantern is shown in Fig. 248, and consists of a rectangular sheet-brass case about 18 inches high, in the sides of which are four openings, without glass or lenses, about six inches in diameter. The whole is riveted and brazed together and at the top are riveted two lugs for a wire brail. The bottom is finished for four feet at the angles. In the center of the top is an aperture about 1¾ inches in diameter through which the lamps can be seen.

Stuffing tubes are brazed in near two of the corners of the top, taking D-13 gaskets with the ordinary gland; a standard socket is fitted to each stuffing tube and inclined so as to lie opposite the reflectors. Two reflectors are used, made of sheet brass and silver plated; to each is attached a hooked brass strap which can be

hooked into straps riveted over each of the side openings. The reflectors can thus be shifted in the lantern as desired. One lamp is to be lighted at a time, though sometimes, but rarely, both are used, depending on the construction of the light box.

The light box is a permanent, water-tight metal casing let down from the deck of the ship and in which is placed large circular glass lenses to admit light into the magazine or shell-room; the lantern is, therefore, designed to lift out or be lowered into place.

Two double conductor, plain, wires, about 18 inches long, are used, with water-tight attachment plugs which plug into the receptacles attached to the inside of the light box.

The lantern is finished in dark bronze.

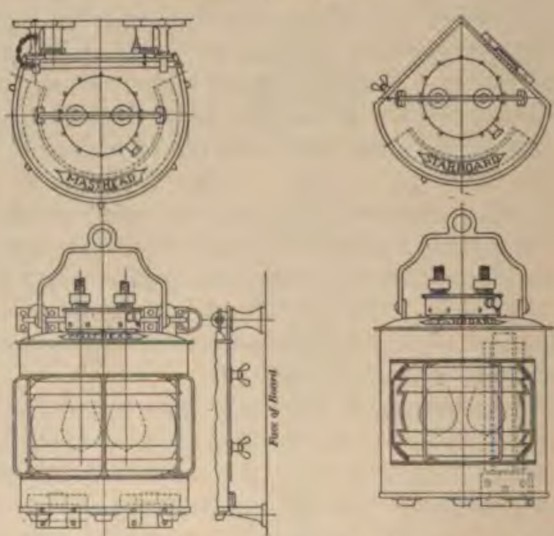


FIG. 249.—Masthead (left) and sidelight lantern.

Running Lights.

The running lights include a white masthead light, and a red and a green light for the two side lights. They are finished in dark bronze color.

Masthead Lights.—The masthead lantern is shown in Fig. 249. It consists of a base and a top made of No. 21 sheet brass, which are held together by five small stanchions, one in the center and two at each side, which also form the guards for the lenses. The top secures to a brass casting, in which are soldered two

stuffing tubes taking D-13 gaskets for packing the two double conductor, plain, wires leading to each of the two lamps with which the fixture is provided. Cast in one with the brass casting are two hollow masses which form the support for the lamps. The front of the base is perforated near the bottom with ventilating holes. To the brass casting on the top is riveted a movable bail for carrying the fixture, and in the center of the top of the bail is an eye to which a halliard may be bent. On the back of the fixture, at the top, are secured two lugs which fit over perforated lugs on the mast fitting; pins secured by chains hold the light in place on the mast. At the bottom of the back are two brass strips which fit over two hooks on the mast fitting and hold the bottom of the fixture.

The lenses are Fresnel (French), clear, cut-glass lenses five sections for each lens, a lens forming a quadrant; four sections are quadrants containing one prism each and the fifth section is a quadrant which is the central plano-convex lens. The lenses are cemented in a brass frame when purchased, a mid frame being used for two sets of lenses to obtain the 180 degree aperture of the light. Although the general shape of the masthead light exceeds a semi-circle, the lenses cover exactly 180 degrees of the circumference.

Inside of the lantern at the back, and extending for a short distance towards the side is a corrugated, silver-plated, polished reflector extending from the bottom to the top.

The hinged door for access to the lamp is on the back. Two wing, socket nuts on the door screw on two stud bolts soldered to the frame and secure the door when closed.

Two 32-candle-power lamps are always installed in this lantern, but it is not intended that more than one shall be used at a time; the second is ready to turn on in case of accident to the first.

The two double conductor, plain, wires are finished with watertight attachment plugs for attaching to the receptacles on the mast near the location of the light. The length of wire is governed by circumstances for the particular ship.

Top Light.—The top-light lantern is identically the same as the masthead lantern, except that it is marked "Top." It is installed on the after side of the after mast of flagships.

Towing Light.—This lantern is also identical in construction with the masthead lantern except that it is marked "Towing."

The arrangements for securing the lantern below that for the masthead lantern are identical with those installed for the latter.

Range Light.—When a range light is allowed a ship a masthead lantern is installed for the purpose.

Side Light.

The side light is shown in Fig. 249.

Its general construction is similar to that of the masthead light except that its frame is shaped at the back to fit the right-angled corners of the light boxes. The lens is identically the same as that used for each half of the lens aperture of the masthead light and is furnished cemented in a composition casing ready for securing to the frame of the light. Just inside of the lens is fitted a guide, at the top and bottom, in which is placed a curved glass shade of green or red glass, accordingly as the side light is to be the starboard or the port light. The hinged door is placed on one side of the back, winged locking nuts being fitted in the same manner as for the masthead light. The top and bottom are secured by two guards only. The casting at the top is similar in construction to that for the masthead light, except as to difference in shape, and of the same general dimensions.

Two 32-candle-power lamps are provided (one only to be used at a time), which are wired with double conductor, plain; the wire lengths are cut to suit the particular ship, and are finished with water-tight attachment plugs which plug into the receptacles on the bridge, or near the side light, if located elsewhere.

To secure the light in the light box a tongue of brass of rectangular section is secured to the after side of the light box; a wide brass strip riveted to the back of the frame of the light slips over this tongue and holds the light firmly in place.

A movable bail is attached to the fixture for transporting.

Signal Lanterns (White, Green, and Red).

The signal lantern is shown in Fig. 250.

It consists of a top and bottom of No. 21 B. & S. G. brass, which are secured together over the lens by the guard posts shown; in addition a guard ring is placed near the top and bottom, to which are attached wire rings through which halliards can be led to hoist and steady the lantern. The top is a casting having but one central stuffing tube for one double conductor, plain, wire

leading to a type-A socket, which is screwed underneath the top of the casting and cushioned by a ring of sheet-rubber packing. The length of the double conductor wire is governed by the requirements of the particular ship; the wire is terminated in a water-tight attachment plug.

The lens is cylindrical with a plano-convex center and prisms, shown, and is in one piece. It is the ordinary six-inch, commercial type lantern lens, and interchangeable with those used in the truck lights, etc. For the green and red lanterns, green or red

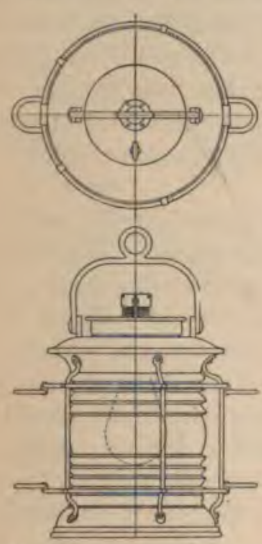


FIG. 250.—Signal lantern.

FIG. 251.—Diving lantern.

glass is flashed on the interior surface of the lens giving the color; the structure of the lens is of white glass. The usual allowance of signal lanterns to a ship is six white, three red, and two green.

Stay Light.—Formerly a stay light with 8-inch lens was prescribed, but the white signal lantern now serves the purpose. A 32-candle-power lamp is used in this lantern.

Stern Light.—The white signal lantern is used for the stern light, being set in a stern light fixture, so constructed that the light will show directly aft and about two points on each quarter.

Peak Light.—White signal lanterns are used for this service, securing to the halliards when hoisting on the flagstaff. More recent practice, when a gaff is available, is to make up a ladder to

which the lanterns can be suspended and connected up by a cable, the arrangement being left in place when the vessel is at anchor; this device is not usual for other than flagships.

Diving Lantern.

The diving lantern (Fig. 251) consists of a casting, to which a type-A socket for a 150-candle-power lamp is secured by two screws and cushioned by a ring of sheet-rubber packing. The top of the lantern is also a casting, fitted with an eye and ring, and is secured to the base by six rods which screw into the base casting and secure at the top by locking nuts. The globe is a cylinder of plain glass without lenses, and is set into two moulded rubber packing rings, which pack the fixture water-tight when the locking nuts are set up. To ensure a tight joint the lower edges of the globe are bevelled on each side.

To the base is screwed and brazed a tube carrying at its outer end a gland which sets up on a B-type gasket; the extension of the tube is a spring with casting and gland setting up on a B-type gasket. The office of this spring is to prevent a nip on the wire at the outer end of the tube, as for the water-tight portable. The conductor used is the especial type of double conductor, diving lantern, and is 100 feet in length; each wire of the conductor is connected to a 25-ampere water-tight attachment plug, which plugs into the two contacts of the 25-ampere receptacle.

The joints of the diving lantern are brazed after assembling so that the top or bottom appears to be a single piece instead of in parts. The finish may be a dark bronze, but the fixture is more often polished and lacquered.

The Double Truck-Light Fixture (Fig. 252).—A cast brass sleeve fits over a tenon on the top of mast to which it is held by eight bolts, if an iron mast, and four through-pins, if a wooden mast. Near its upper part are cast the cheeks for the sheaves for the signal halliards, and gussets upon which the base plate shoulders. The base plate is a brass casting threaded on its collar to screw into the top of the sleeve casting. At one side of the base plate is a vertical flange to which is bolted a square copper lightning rod, 46 inches long; the lower end of the rod is drilled for soldering in a copper lightning conductor; the upper part of the rod is bent in to cover the fixture. The flange is so located on the

base ring that the plane of the lightning rod will set 45 degrees abaft the plane of the athwartship line, and on the port side.

The base plate is drilled for four flathead, countersunk bolts which secure the urn-shaped section which forms the base of the fixture proper. Two large hand holes are cut in this section for access to the gland, lamp, etc., of the lower (white) half of the lantern.

The upper part of the urn-shaped section is flanged for the four posts which support the cover of the lantern which secures the lenses. The inner side of the flange is threaded for the base ring; when the base ring is screwed in place the joint is soldered.

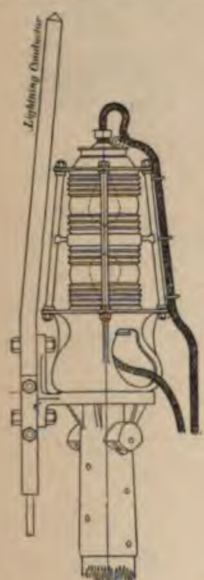


FIG. 252.—Truck-light fixture.

FIG. 253.—Truck-light controller.

The lantern base, coned for a D-13 gasket, is held to the base ring by a cap ring; the joint at the base ring being packed water-tight by a sheet-rubber packing which also forms a cushion for the type-A socket. A similar arrangement exists in the construction for the lamp and socket, in the upper half of the lamp except that the base ring is a part of the cover casting.

The cover piece is drilled to correspond with the holes for four shouldered posts, which have threaded stud ends to take the nuts. A ring acts as a blank flange, or diaphragm, between the upper

(red) half of the lantern and the lower (white) half; this ring has arms with flanges, the flanges being soldered to the posts. Riveted to that post which is diametrically opposite from the lightning rod are three rings, through which is rove, and to which is seized, the length of double conductor, plain, lightning wire which feeds the upper lamp; to prevent a nip at the upper gland the conductor is seized to a cast gland.

The lenses are fitted in between the diaphragm and the base or the top, and are set tight in cement by the nuts of the posts; these are ordinary commercial, six-inch, pressed-glass Fresnel lenses; the upper lens is red, the red color being imparted in manufacture by flashing red glass on the interior surface of the ordinary white lens.

The many parts of the fixture are to afford convenience in replacing lenses, sockets, and lamps aloft. Once installed the sleeve and the base plate become an integral part of the mast as the fixture proper above it can be sent down by unscrewing the nuts.

Lamps of 32-candle-power are always used in the lantern of this fixture.

Truck-Light Controller.—The double truck-light controller, for two masts, is shown in Fig. 253; a modified construction is installed on single-masted ships.

It consists of a composition casting open on the back and front; the openings being made water-tight by back and front plates and sheet-rubber gaskets. Each plate is secured to the casting by eight machine screws. The casting is usually secured to a hollow pedestal of the same metal, which is fitted with a hard rubber tube through which the wires are led to and from the controller. On the top of the casting is a boss through which is passed a spindle having on its upper end a lever and pointer, cast in one piece with it, and recessed to fit over the boss to prevent water from entering the casting. The lower end of the spindle is steadied in a hole drilled in the lower cross bar of the casting. The lever and pointer may be moved to any one of six positions as indicated by the words, "Red, Off, and White" for the fore, and "Red, Off, White" for the main truck lights, respectively, on the right and left of the top of the casting. The pointer is retained in any of the above positions by means of a plunger and spring which engages the notches on a cam secured to the spindle.

The switch barrel fits on the spindle and is kept in place by a set screw. Secured respectively to the top and bottom, and insulated from the switch barrel, are two switch contact rings. Secured vertically to the inner part of the casting are four micanite contact spring insulators, to which, in turn, are secured the phosphor bronze contact springs and wire terminals.

Facing the front of the controller, the lower left hand contact spring in front of the casting connects to one of the line wires and has the pulsator in circuit. The other side of the line connects to the right hand upper spring at the back of the casting. The leads for the red light on the mainmast connect to the upper left hand contact springs, and those for the white light on the mainmast to the contact springs on the right hand side of the front of the casting. The circuits for the red and white lights on the foremast connect to the contact springs in the back of the casting directly opposite those for the mainmast.

The pulsator consists of a knob, spindle, washer, collar, contact carrier, and spring. The knob is secured to the end of the spindle which projects through the left side of the casting, and the other end of the shaft is seated in the projection on the inside of the casting. The washer of the spindle serves as a gasket to prevent moisture from entering the casting. The collar controls the outward thrust movement caused by the spring. The contact carrier of the spindle, normally in contact with the lower contact springs, maintains the continuity of the lower line wire until the pulsator knob is pushed in, which action disengages the contact carrier from the contact springs and opens the circuit.

The operation of the controller is as follows: Moving the pointer, say, to the red for the foremast, the line wires being in contact with the switch contact ring permanently (unless the pulsator is operated), the current passes through the projection on one side of the switch contact rings, through one of the springs marked F-R (Fore Red), through the lamp in the upper half of the lantern, and back through the other spring marked F-R (Fore Red) to the projection on the other switch contact ring and the other line wire. When the pointer is moved to "Off" the projections on the switch contact rings are thrown clear of the springs thus opening the lamp circuit.

The truck light on the fore has two purposes: one is for use for signalling; the other is in case of any defects in the truck light on

the main, that it can be substituted for it. The same rules apply to its use under these circumstances as have been stated for the main.

When connecting the wires on the controller the following rules must be observed: The terminals attached to the contact springs have a small hole drilled in them into which the wire leads must be soldered. The line wires connect to the terminals of the contact springs which are marked "L" (Line), and the leads for the upper half of the lantern (red) on the foremast connect to the terminals of the springs marked F-R (Fore Red); the leads for the other half of the lantern to the springs marked F-W (Fore White). The leads for the lights on the mainmast are connected similarly, the white connecting the springs marked M-W (Main White) and the red to those marked M-R (Main Red).

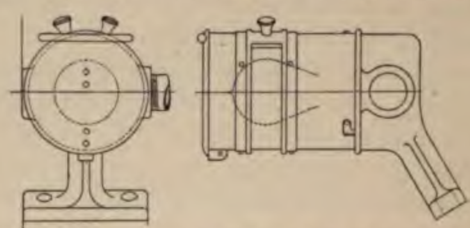


Fig. 254.—Turret-hood fixture.

The back and front covers of the controller case should be removed at least once every two months, and the contacts which have become discolored or corroded should be replaced or repolished, and any irregular or burnt places should be smoothed by emery cloth *but not filed.*

The plunger and spindle require occasional oiling.

The Turret-Hood Fixture (Fig. 254).—It consists of a sheet-brass barrel attached by screws to a casting. The flange of the casting arm is secured at the top of and back of the sight hole in the turret hood. The casting forms the base for a socket for a 5-candle-power lamp which throws its light through the end of the fixture into the sight hole. This enables the officer to see the cross-wires of the telescopic sight. The end of the barrel can be closed by a door.

In the side of the barrel is a small port through which light can be thrown down on the graduations on the drum of the telescopic sight; a slip ring closes and opens this port.

Telegraph Fixture.—The fixture, shown in Fig. 255, is intended to replace the oil lamp which lights up the dial of a mechanical engine-room telegraph. There are two types for the varieties and size of telegraphs. The fixture consists of a cylinder in the top of which is secured the socket for a 5-candle-power lamp.

The stuffing tube at the side takes a double conductor, plain, wire with D-13 gasket; the conductor is finished off with a watertight attachment plug and is long enough to reach a hooded receptacle which is installed on the pedestal of the engine telegraph.

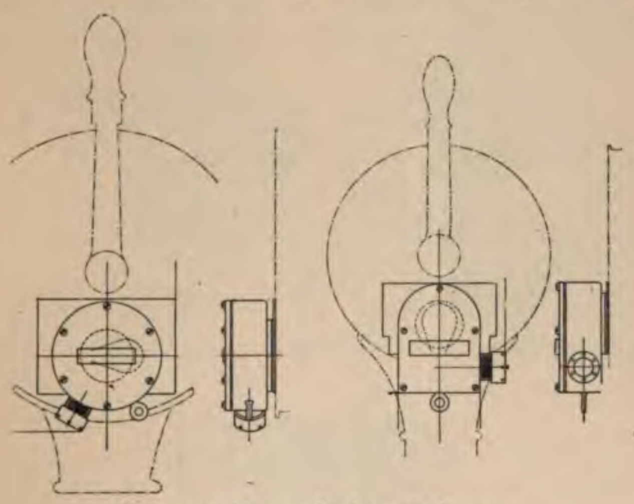


FIG. 255.—Types of telegraph fixture.

The cylinder is attached to a rectangular plate of brass, perforated in the center for the diameter of the cylinder for the passage of light, the opening being covered by a thin sheet of mica; this plate fits in the guides on the back of the telegraph which were intended for the oil lamp; the oil lamp, or telegraph light, can, therefore, be used at will. The fixture is finished in dark bronze.

Binnacle Lights.

The type for ships' binnacles (Type VI) Fig. 256, left, consists of a cylindrical attachment fitting through the binnacle cover (dotted lines). A type-A socket is fitted inside holding a 16-

candle-power lamp which shines vertically down through an orifice in the bottom of the device and directly upon the face of the compass. The device is removable by a bail at the top. For oil lighting a separate top is provided, that carrying the electric lamp being removed; this top is fitted with a reflector and the oil pot is set off center.

The type for torpedo-boats (Fig. 256, right) differs in being designed to be inserted in the side of the binnacle cover. No oil arrangement is necessary as a separate lamp can be used in case of failure of electric energy.

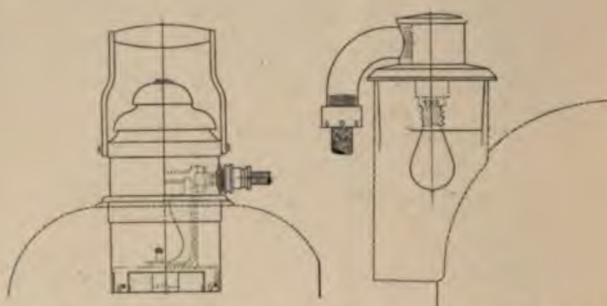


Fig. 256.—Binnacle light for ships (left) and torpedo-boats and destroyers.

Fig. 257.—Lantern for night-signal set.

Lantern for Night Signalling Set.

The type shown in Fig. 257 is that now used for the purpose (see also Fig. 269). It is made of composition or bronze, usually finished in a bronze color and consists essentially of bottom and top castings containing the stuffing tubes for the circuit wires, the top and bottom pieces being held together by four side rods.

The lenses are 6-inch and are cemented to the top and bottom pieces and to a separating diaphragm; the upper lens is red, the bottom lens white.

Type-A sockets are used and so disposed that the upper lamp will drop and the lower lamp will stand vertically.

Fixtures and Lanterns for Torpedo-boats.

Masthead Lantern.—The type (Fig. 258, upper left) is a modification of that for ships, and is fitted to be used with oil also, the upper closing cap being removable and can be replaced by a ventilating chimney. As mineral oil is ordinarily burned, a glass chimney for the burner is necessary. The lens is 4½ inches.

Side Light Lantern.

This is constructed (Fig. 258) for use with both electric and oil light. As no light boxes are installed on the boats, the lan-

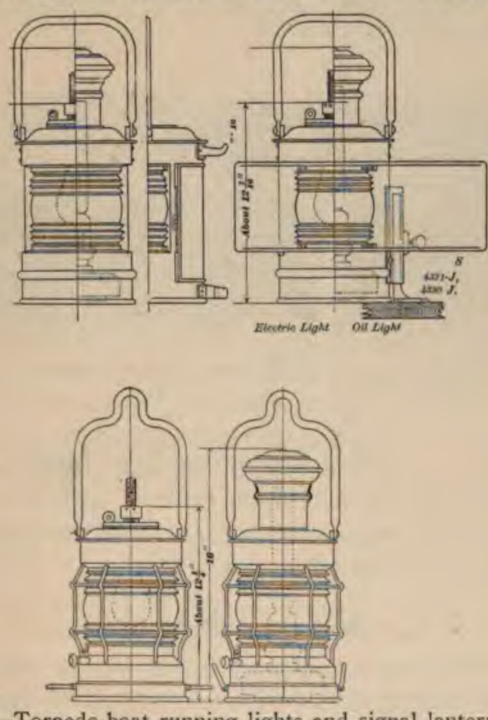


FIG. 258.—Torpedo-boat running lights and signal lantern.

tern is fitted with a screen whose angles are such as to conform to the law that the light shall show from directly ahead to two points abaft the beam, but not across the bow. The lens is 4½ inches.

Signal Lantern.

In this design a removable cap for the electrically lighted (Fig. 258, lower left) can be replaced by a ventilator (Fig. 258, lower

right) following the general method pursued in the masthead lantern.

The lenses are red, green, and white, with color blown on, and of the same size as those of the masthead.

Truck Light.

In its best form this fixture is simply a reduced dimension of that for larger vessels, the reduction being made to conform to the same size lenses as are used with the torpedo-boat masthead lantern, 4½-inch. But one is installed on each boat and only a single controller is placed.

FIG. 259.—Water-tight vibrating bell (left); water-tight single stroke bell (center) and buzzer.

Night Signal Set, Two Light.

A single night signal lantern, reduced in dimensions to conform to the 4½-inch lens, is located on the forward side of the mast. Signals are made by wigwag, 1-2 code.

Magazine Light Fixture.

The general construction of this fixture is modelled after that of the overhead bunker fixture which it closely resembles, though smaller in dimensions.

CHAPTER XIV.

INTERIOR AND EXTERIOR COMMUNICATION.

Call Bells.

Under this signification is included all such material as is used for simple methods of calling attention to the point of origin of call, by bell, or buzzer, and by annunciator indication.

Bells.

There are two classes of bells, water-tight and non-water-tight, and each class is of two kinds, vibrating bells and single stroke bells.

Water-tight Vibrating Bells.—There are two sizes, 6-inch and 3-inch, differing only in the size of the gong.

Fig. 259 shows the 3-inch size having the usual vibrating arrangement (as explained in bell circuit below) for the bell and also a compartment containing the vibrator and contacts, the mechanism and contacts being water-tighted by a cover and packing, as in the case of water-tight wiring appliances. The circuit wires are brought through a stuffing tube in the back. All mounting insulating material, including magnet heads, should be hard rubber.

Non-water-tight Bells.—There are two sizes, 5-inch and 2½-inch, corresponding to the usual commercial types. The cover is a box which fits over the mechanism, hooking by a lug in a recess on the gong side to give a kind of hinge effect and securing on the opposite side by a snap spring, the spring and lug to be sufficient to insure that the cover will not fall off under gun-shock or mechanical shock or jar.

The mechanism is similar to that for the water-tight bells, omitting the features essential to the water-tight construction.

Water-tight Single-stroke Bells (Fig. 259).—The essential difference between vibrating and single-stroke bells is that when the circuit is closed for the latter, a single stroke only is made on the gong instead of the vibratory, successive strokes for the former; single-stroke bells, therefore, require a spring attach-

ment for their armatures, but no interrupting contact. The pattern and mechanism, omitting this feature, is the same as that of the vibrating bell. All water-tight, single-stroke bells have 6-inch gongs; they are used in water-tight compartments, and generally as signals for the departure of boats.

Non-water-tight, Single-stroke Bells.—These have the same general construction as the non-water-tight vibrating bells omitting the interrupting contact.

Buzzers (Fig. 259).

There are two classes, water-tight and non-water-tight.

Their construction is similar to that of the vibrating bells, but, instead of a gong, the clapper or armature strikes against the

FIG. 260.—3-drop water-tight annunciator.

magnet cores. They are used mainly in connection with annunciators, but are sometimes used when the noise of a bell would be too great, or where it is desirable to distinguish from a bell call in the same compartment or location.

Other types of bells are installed than those shown in Fig. 259, and differing in details of construction.

Annunciators.

This apparatus affords a convenient method of grouping a number of calls at one location, the apparatus indicating the station from which the call originated and at the same time a bell or buzzer, in series with and in common for all the drops, sounds and calls attention.

Fig. 260 shows a three-drop water-tight annunciator with the

mechanism heretofore in use; there are at least three types of drop in use. The particular style shown is that classed as the gravity shutter drop as distinct from the needle drop in whose mechanism arrangement is made to move a needle to an indication marked on the face of the dial.

The drop is an electromagnet circuit which when magnetized attracts armatures fitted with the notches which hold the shutter in its normal position; the shutter then falls and exposes the indication through a square hole in the instrument face, the bell or buzzer sounding at the same time. A bent rod (shown) can be pushed up by the push handle and restore the shutter in the catch of the clutch. In present designs the push is made flush with the case and covered water-tight by pigskin or lace leather as in the water-tight push button; the case is also made more securely water-tight by securing with flathead screws instead of wing nuts.

For the non-water-tight annunciator the case is made of mahogany with a hinged face and the drops are attached to the case.

Water-tight annunciators often contain a large number of drops (as for fire alarms and magazine alarms), but the non-water-tight types rarely exceed 24 total. The arrangement of the indications is for so many "high" and so many "wide," as may best suit the position in which they may be installed; for instance, a 24-drop annunciator may be either 4 high and 6 wide, or 6 high and 4 wide.

Primary Batteries.

The installation of primary batteries is usually inadvisable; they polarize and lose voltage from even slight grounds on the lines; the room for battery lockers is generally difficult to set apart. The advantages of transformers is discussed under those machines.

Cells.—The liquid cell in general use is the form of Leclanche known as the Gonda. There are other types of merit, but the supply is mainly confined to the Gonda in order to avoid many types of spare parts. The negative element (positive pole) is a carbon plate with conglomerate blocks attached without the porous cup; the positive element (negative pole) is a zinc rod. The liquid used is a solution of sal ammoniac, 5 ounces of the salt per cell.

Polarizaton of this cell is indicated by a milky appearance of the liquid.

The zincs last longer if amalgamated by first cleaning and then dipping in mercury until uniformly coated.

For torpedo-boats and destroyers the type of primary battery is one of the many forms of dry cell. Dry cells cannot be restored when once run down and must be replaced.

Telegraphs and Indicators.

In many of this type of apparatus the visual method of reading the signal is employed, the indicator containing small lamps which

FIG. 261.—Parts of contact for operating helm angle indicator system.

illuminate legends on discs, the lamps being set in compartments to illuminate a single disc only. Of these "lamp-indicating" devices the helm angle indicator was the original and its method of lamp installation is pursued in the others.

Helm Angle Indicator.

The object of the helm angle indicator is to show at all times the relative position of the tiller to the keel of the ship. The system consists essentially of a contact arc, a contact maker, and an indicator, with the necessary wire connections.

The helm is provided with a contact as shown in the upper part of Fig. 261, consisting of a cast bracket which is bolted to a fitting piece attached to the rudder head; insulating bushes and plates prevent it from grounding.

In two vertical holes are fitted hollow plungers in which carbon

cylinders are secured by clamping screws and shoes; these carbons make moving contact with the continuous and divided arcs. Spiral springs, pressing between the top surface of the bracket and shoulders cast on the plungers, maintain the carbons in contact.

Earlier patterns of this apparatus had only the divided arc and a single plunger contact. This construction required a flexible connection to the contact which involved the likelihood of being jammed in the moving parts.

Two brass arcs are contained in the contact box (Fig. 261) one arc being divided into 15 contact sections, insulated from each other, and the other arc being continuous. The contact box is made in the form of a segment of a circle, and is open on its lower

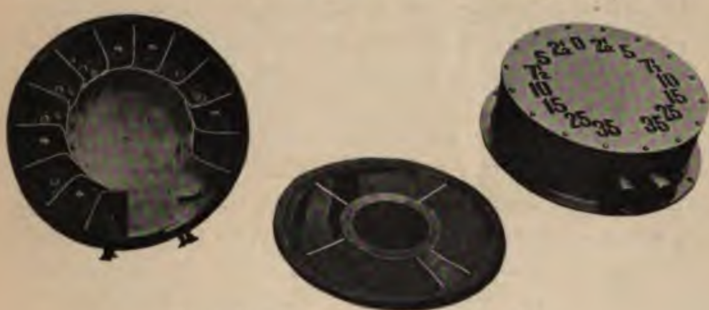


FIG. 262.—Indicator for helm angle.

surface to permit the contact maker to travel along the surface of the arcs. The box is closed on the upper surface by a cast iron cover made in two sections and secured to the box by tap screws; rubber gaskets under the plates water-tight the box from above.

Each of the 15 contact sections is connected by wire to one lamp in the indicator (Fig. 262), and which is cut to indicate seven angles of the helm, starboard and port.

The contact sections correspond to the different angles of the helm, and are of such widths that the insulated separations are half way between all indicated angles. The center section is designated zero, and corresponds with the position of the tiller when it is parallel to the keel of the ship. These contact sections are secured to a mahogany insulated block, made in three thicknesses and glued together with the grains crossed. The block is faced with micanite, is secured to the casting along its entire length with

machine screws, and is made water-tight to the casting by a rubber gasket. The manner of securing the section is, in the case of the small ones, by machine screws passing through the mahogany block and securing into the brass terminal block, furnished with a sheet copper terminal into which its respective wire is soldered. In the case of the larger section one or more metal blocks are used to secure the section in addition to the terminal block.

One side of the line, used for the common return wire for the whole system, is connected with the continuous brass arc shown; the other side of the line is connected to the plate containing the contact sections. The contact maker operates between these plates.

The indicator (Fig. 262) consists of 15 instrument lamp sockets for fifteen 5-candle-power instrument lamps, all contained in a circular brass casting which can be opened in front, being closed by a cover which is secured to the casting by screws. The figures conform to the nearest angle of the helm, but by an arrangement of the contact sections *the break is made half way between each indication,* that is, one indication is still on until the tiller has reached the position half-way between that indication and the next, when the next indication is switched on across the insulation.

The figures on the left half of the cover are backed with red glass cemented to the cover which, when the instrument is working, show when the tiller is to port. The figures on the right half of the cover are backed with green glass and show when the tiller is to starboard. The zero marking is backed with white glass and shows when the tiller is amidships.

The sockets with lamps are arranged in an incomplete circle and secured in the case, each lamp being behind its respective figure and separated from the adjacent lamp by a wall of sheet brass which prevents the illumination of any other figure than the one indicated by transmission of light from one lamp compartment to the other.

The indicator is commonly secured to a hollow brass pedestal, through which the 16-wire cable is run. One of the wires in the cable is the common return and is connected to one terminal of each lamp socket; the other terminal of the lamp socket is connected, respectively, to one of the remaining 15 section wires. The other end of the cable enters the contact box, and each wire connects to the terminal block of its respective section; for instance,

the wire from indication 2½, port, on the indicator, connects to the first section of the transmitter arc on the port side of the zero; and for 2½, starboard, on the indicator, a wire connects to the first block on the starboard side of the zero section, and so on. The common return wire secures to the continuous arc.

The operation of the system is as follows: The current is switched on, and the controller being moved to, say, 10 degrees starboard, the circuit will be from the line, through the contact maker, to the section on the arc corresponding to 10 degrees starboard, through the section wire to the lamp in the rear of Figure 10, starboard, on the indicator, and then by the common return wire to the other side of the line, through the continuous arc of the box.

When the system is not in use the plungers should be slipped into the slots on the tubes of the contact maker, and should be let down on the arc before switching on the current. When the system is to be used, *the plungers should be eased out of the slot,* otherwise the carbon point is liable to be broken by striking the arc too violently. The contact plate should be kept clean and all connections kept tight to ensure good results. The only repairs to which the system is liable are wearing or breaking of the carbon contact point or breaking or burning out of lamps. The system is simple, and, with ordinary care, is not liable to get out of order. As many indicators as may be desired may be installed on the same circuits by paralleling across the cable leads through the connection box.

Steering Telegraph.

The transmitter of this apparatus is similar to that shown in Fig. 263. Its indications are cut for the angles of helm corresponding to those of the helm angle indicator with the addition of a "steady" order.

The transmitter includes its own indicator, as described for the engine telegraph, and consists of a pedestal with a cylindrical case, the latter containing the mechanism for ringing a magneto bell at indicator stations, and for causing an electric light to burn behind the figure on dial of the station indicator.

On the spindle of the operating handle is a metal wheel geared to fit a sprocket chain; this chain leads down into the pedestal to the multiplying gear, and thence another sprocket chain leads to

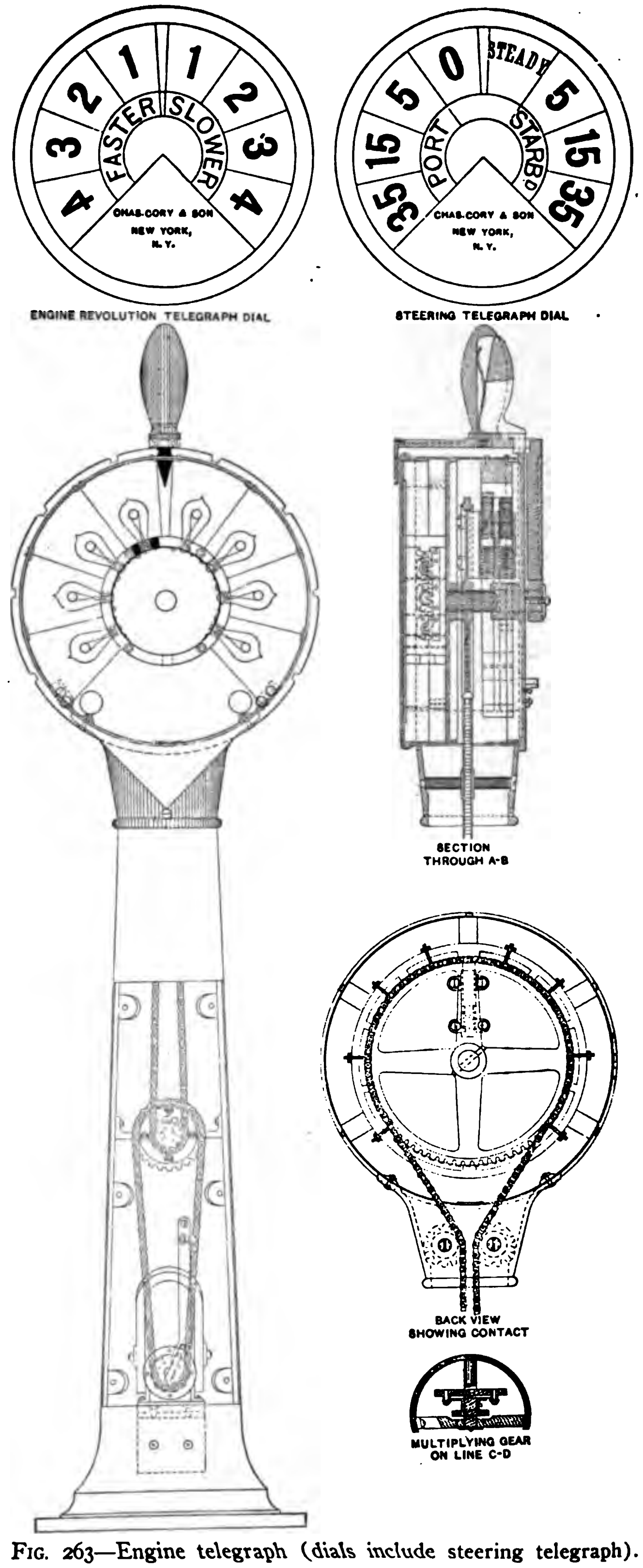


FIG. 263—Engine telegraph (dials include steering telegraph).

the armature of a magneto generator, secured in the pedestal. Wires are led from the brushes of the magneto to the magneto bell in the steering engine-room or to steering wheels.

Secured to the sprocket wheel of the transmitter, on the rear side, is the contact maker, insulated from the wheel and constructed on the same general plan as for the engine telegraph. The current paths are alike in each telegraph. No reply is required as the helm angle indicator shows the action taken by the helm.

A metal plate divides the transmitter into two parts, that part in front forming the indicator. The indicator is of the same general construction as that for the helm angle indicator, the face being cut for orders identical with those on the transmitter shown in Fig. 263.

A water-tight magneto bell is installed near each indicator at the steering stations.

To give an order by the steering telegraph it is necessary to move the handle over the entire arc of the face to give ample alarm in the ringing of the magneto bell. The pointer of the lever should be left in the center of the division containing the required order, and the clutch should drop into the notch; an alternating current will be generated by the magneto, ringing the bell at the steering stations; contact will then be made on the lamp circuit, lighting the lamps behind the required order on each indicator.

To farther assure the orders at night when the words "starboard" and "port" may not be distinguished, the port indications show through a red glass, the starboard through green glass; the "O" and "Steady" show white.

The different station indicators are connected up in parallel on the same transmitter circuit.

Engine Telegraph.

The difficulty of obtaining a direct-reading device which will certainly indicate, over practical periods, the number of revolutions at which it is desired that the engine shall drive has occasioned the adoption of the plan of establishing a standard number of revolutions for the standard speed and regulating the speed by indicating so many turns faster or slower, up to four turns in the standard telegraph. This range appears small for engines making averages of about 8 to 10 revolutions per knot, but can only be

altered for the especial cases by increasing the size of the telegraph. The design is not installed in small conning towers.

The design of transmitter (Fig. 263) is similar to, and a modification of, the steering telegraph in so far as the method of indicating is concerned. There is no method of reply for some of the types. In later constructions the indicator is of similar construction to the transmitter and a reply back is obtained by setting the transmitter, after ringing up, to the indication desired; this gives indications both in the transmitter and in the indicator. The transmitter lever is then put back to the off point and the indicator lever is put to the indication received; this gives indications at both ends as a reply back similarly to the original transmission of the order.

The transmitter includes its own indicator in order that the signal made may be checked at night, when the pointer would not be visible; the indicator, consisting of a set of lamp indications spaced and marked similarly to those of the telegraph, corresponding indications show the same in both for the same signal. The form of the transmitter, its operating handle and clutch, resembles the mechanical engine-room telegraph, and which it duplicates.

The indicator (Fig. 263) consists of a set of eight 5-candle-power lamps, whose sockets are mounted on a vulcanized rubber base behind the face of the dial. The dial is a brass plate with the numbers 1, 2, 3, and 4, cut through on each side of a vertical line. A white glass is behind the numbers on the side marked "faster" and a red glass behind the numbers on the side marked "slower." The telegraphs are generally mounted with the faster side forward and slower side aft.

The sockets for the lamps are fitted to the hard rubber base and the connections to the wires are made in the center. Each lamp is connected to the common return and to that section wire which connects with the corresponding metal strip in the transmitter.

Each lamp is in a separate compartment, so that it can illuminate only one of the perforated numbers. Strips of sheet brass are fitted between the lamps.

The indicator in the engine room is similar to the indicator in the transmitter in all respects, except that it is mounted on a bracket instead of on a pedestal; the water-tight magneto bell is installed near the engine-room indicator.

To give an order by the telegraph, move the handle over the

entire arc of the face to give ample alarm by the ringing of the magneto bell. The pointer of the lever should be left in the center of the division showing the required order, and the clutch should drop into the notch. An alternating current will be generated by the magneto, ringing the bell in the engine room; contact will then be made on the lamp circuit, lighting the lamp behind the required order on each indicator.

"Battle Order" and "Battery Control."

Telegraphs and Indicators.

The systems included under these designations, though still installed in a number of vessels, are probably to be superseded by entirely different designs and not yet approved.

FIG. 264.—Cory engine revolution indicator.

Engine Revolution Indicator.

This device is for the purpose of indicating at the bridge the number of revolutions which each shaft is actually making. The usual type is the Cory device.

Cory Type.—The objection to the Cory type of instrument is that it is not direct reading; it has the important advantages that its construction is simple, it will operate for long periods without getting out of order, and it is reliable; when it fails, the occasion is usually from corrosion or burning out of the contacts of the transmitter at the shaft.

Fig. 264 shows the indicator for one shaft which is mounted on the bridge and in the conning tower, and Fig. 265 the connections and essentials of the circuit.

A cogged eccentric is attached to the shaft and revolves with it. A cogged wheel gears into this eccentric and has an upright,

carrying a lever arm which makes contact with springs; this combination can swing about a center at, and in each revolution the cogged wheel is dragged enough in the direction of rotation of the shaft to make contact at the springs accordingly as the engine is going ahead or astern, and always on the same spring for the same direction of revolution. At each of the springs are connections to two electromganets in the indicator; but three wires being necessary as one wire answers as a common return for both. An armature connected to the pointer of the dial is at-

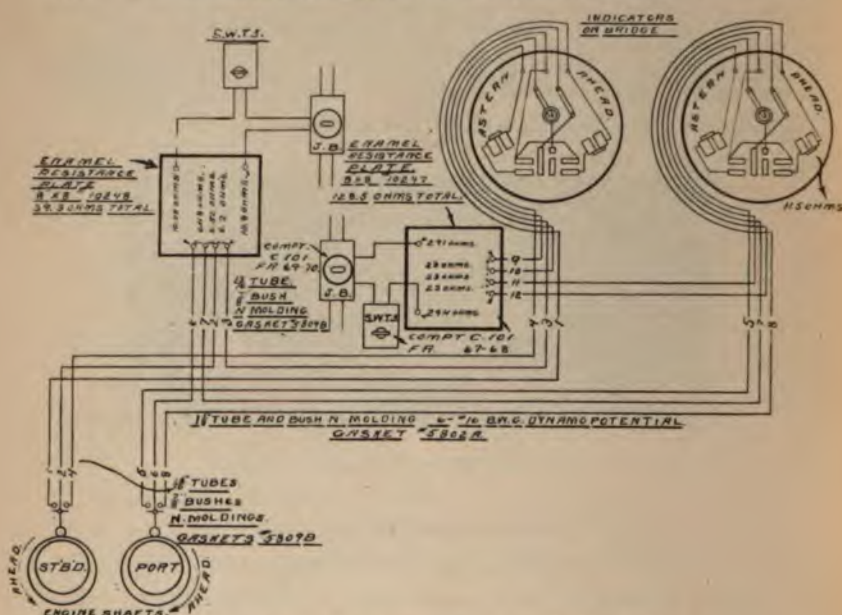


FIG. 265.—Connection details Cory revolution indicator.

tracted by the magnet, which is energized, and is arranged with a sounder to give an audible "tick" at each attraction (each revolution).

The contact lever arm and the springs are enclosed in a box. The assemblage is made on an oblong piece of slate on which a flat brass spring, mounted on a terminal block, is secured at each of the upper corners, these two springs are the electrical contacts for "Ahead" and "Astern." The wire from the corresponding magnet in the indicator connects to each of these terminals. Near the middle of the slate a lever arm is pivoted, and is slotted to

work on a pin and permit of an up and down throw; the upper end of the lever is fitted with a lead counterbalance weight, the lower end is forked and embraces the gear wheel, the gear wheel being insulated from the fork by a hard rubber bushing. The fork carries a holder on each arm and each holder has a hard rubber insulator, which, by means of a spring, presses against the gear wheel and keeps the latter from contact with the fork and prevents grounding of the electrical circuit at that point. A wire for current supply from a battery or transformer circuit connects to a binding post on the right of the slate, the binding post being connected directly to the lever arm; the lever arm is electrically insulated from all other parts of the mechanism.

The shaft-eccentric-ring is of composition, and made in two halves for facility of assembling on, or removal from, the shaft. One part of the periphery is plain and drilled to bolt to the engine shaft, the other part is eccentric and cut with teeth to engage the gear wheel.

The contacts should be kept clean and all connections tight; parts requiring lubrication should be occasionally oiled. The requirement of operation is that there should be sufficient current in the line to energize the magnets of the indicator; it is independent of variable resistances in connections, provided that the requisite energy is supplied.

Fire Alarms.

Magazine Alarms.

The apparatus for these services consists of thermostats so located as to give automatic intelligence of a rise of temperature above a designed maxima. Several types depending upon the expansion of mercury and melting of easily fusible alloys have been used, but are found to be inefficient. In mercurial types the oxidization of the surface of the mercury causes unreliable contact. The present types depend on the uncoiling of a spring; these types are really two, a water-tight type for coal bunkers and a non-water-tight type for magazines. Each of the two types has two varieties (A and B for fire alarms, C and D for magazine alarms) differing as explained below.

The type-A thermostat for coal bunkers consists of a composition box, with cover, and lugs for securing to the bulkhead or

deck, within which is secured the interior fitting shown in Fig. 266.

The type-A interior fitting consists of a coiled spring made of two metallic ribbons brazed together, one brass and the other steel (known as a thermostatic bar), and afterwards surfaced with a protecting coating of tin. The lower end of the spring is screwed to a lug on the base of a spindle which runs up through the center of the spring and ends in a casting; this casting being so shaped as to be secured by screws to the containing plate over mica insulation and to extend up to take the wire contact as shown on the left. The top of the spring is free and has secured to it a brass contact lever, about one inch and a half long, pivoted over a pin to restrict the motion to the circular as near as may be and give a firm contact. The outer wire contact, shown on the right is a casting, also secured over insulation, through whose end travels the set screw shown, and having a screw contact for securing the wire.

When the spring is heated it twists, and the bent contact tends to revolve and touch the set screw, thus making electrical connection in the circuit. The distance the set screw is set through its holder determines the necessary motion of the bent contact to bring it into contact with the set screw, and as this is dependent upon the expansion of the spring, and upon the temperature, the apparatus can be set by trial for the temperature desired—200 degrees Fahrenheit in this instance. The set screw has a capstan head for facility in making adjustments and a screw locks it in the position determined.

The type-B interior fitting differs from the type-A in having two extra contact lugs on each side, admitting of connecting in four other thermostats of the type-A style through its box. The type-B is thus a combined thermostat and connection box, while the type-A is intended only as the terminal of a run. The difference in use is: In a large compartment requiring a number of thermostats in different places, the supply cable is branched from a connection box into a type-B thermostat from which the other thermostats in the compartment (five are not unusual in one compartment) are connected in series, the system for the compartment being on one line to the annunciator. For the other thermostats in the compartment the type-A would be used except as necessary for the type-B connections; if but one thermostat is

installed in the compartment a type-A is installed. The boxes for the two types differ in shape and size.

The type-C thermostat, for magazines, is essentially the same as the type-A, though differing somewhat in features of construction and in being smaller. The differences between the C and D types are similar to those for the A and B, and for similar reasons; there is also a difference in the spindle details at the bottom connection.

The main difference in construction between the bunker and magazine types is in the direct exposure of the magazine type of thermostatic coil to the air and that protection from mechanical injury and overhead drip, etc., only are afforded. This is necessary by reason of the more rapid inflammability of the contents

FIG. 266.—Interior fitting of thermostats.

of storerooms and the necessity for more delicate indications of a change of temperature in magazines. In bunkers the usual cause of ignition is due to slow spontaneous combustion and the feature of rapid indication has been sacrificed in favor of water-tightness. The practice of locating the type-A thermostats low down on bulkheads and embedded in coal, renders the water-tight features especially desirable.

In recent types superseding the C and D, the interior fitting is wholly enclosed so that inflammable gases within the magazine are excluded from access to the spark of contact.

Warning Signal.

This apparatus, sometimes called a shrieking whistle, was originally intended as an adjunct to the syren warning to close water-tight doors or for collision, and to be located in those compartments whose occupants cannot hear the syren. While the original intention still obtains in some cases, the standard and more common use of the apparatus is as an adjunct to the general alarm gongs, the difference in installation being that the warning signal is installed in conveniently located positions below the protective deck only, and the general alarm gong in spaces above that deck; this division appears to be the most efficient and economical.

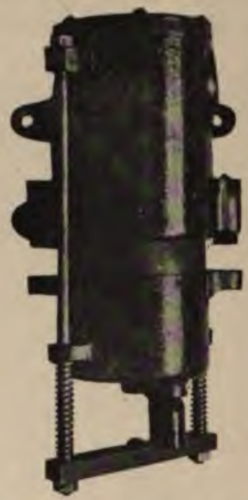


FIG. 267.—Warning signal.

A circuit closer for operating the system is located on the bridge (none are usually installed in conning towers). It consists of a brass base with a rectangular cover, packed water-tight by a cloth-insertion sheet-rubber packing. Upon the base is mounted a clock-work mechanism (similar to that of the electro-mechanical general alarm gong) controlled by a lever on the outside of the cover. A heavy coil spring actuates the mechanism and is secured to a control spindle to which the lever is attached. On the drum of the spring is a gear wheel meshing into a small pinion on the spindle of a five-pointed star wheel carrying anti-friction rollers in the ends of the star points. The uncoiling of

the main spring, which has been compressed by manipulating the lever on the outside of the case, causes the star wheel to revolve clockwise. A chain of gears down to the contact escapement controls the speed of the unwinding of this spring. On the inside of the water tight case and secured to the framework of the mechanism is an arm, pivoted at its extreme left-hand end, and carrying at the other end the contact for making and breaking the circuit. On the lower side of this arm is a V-shaped lug, resting normally between two of the points of the star wheel. When the star wheel revolves, the lug is lifted by the roller of each point of the wheel until the roller passes the angle of the lug when the lever drops back by its own weight. On the right hand end of the contact lever are two carbons insulated from the arm, and furnished with adjusting screws. These carbons make contact, when the lever is raised, with two carbons carried on the case and to each of which the line wires are connected, thus making the circuit. A double contact is made on the contact maker, the first by the carbons on the base, the second by metallic contacts on the lever and base, adjacent to the carbons, but making contact after the carbons have touched each other. The dimensions of the carbons are ⅜ inch by one inch. This construction allows the carbons to receive the spark at breaking the circuit, but as the resistance of the carbons is too great to give sufficient current to the solenoid by carbon only, the metal contacts are made in addition. (In adjusting these contacts, allow very little lead of the carbons, otherwise the period of contact of the metal contacts is made too short to allow the reciprocation of the core of the solenoid.)

The signal is shown in Fig. 267.

A composition case forms the chamber for the wire terminals, the space for conduit terminals, the lugs furnished with rubber cushions which receive the impact of the core-case when the circuit is closed, and the lugs for securing the whole to the bulkhead. The composition case has two lugs cast on its upper part to which are secured one end of each of the two steel guide rods on which the core-case travels; the other end of each rod is passed through a brass washer and spiral spring and is connected to a composition cross-piece which has a rubber cushion on its center; the rubber cushion together with the spiral springs on the rods serve as buffers to receive the weight of the core-case when the circuit is opened. A water-tight cover of composition is fitted on the top

of the case, which, when removed, exposes the wire terminals. Each wire terminal has a 3-ampere link fuse mounted on a porcelain block; the fuses are more often omitted.

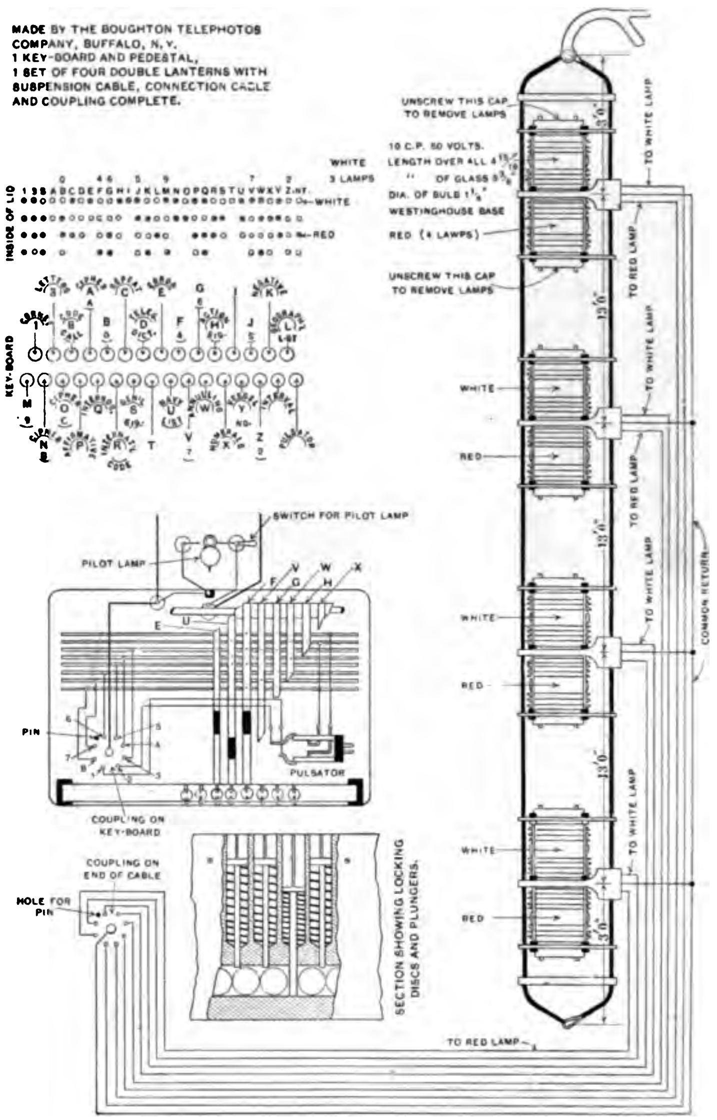


FIG. 268.—Connections and arrangement for the telephotos.

The solenoid coil is secured to composition case and is encased in a brass cylinder; it has a hollow center about one inch in diameter.

The iron core-case, forming an air chamber below the solenoid, is a hollow cylinder fitting closely over the outside of the coil and inside the composition case. It is closed at the bottom and carries the core of soft steel which projects into the solenoid coil. The whistle is attached to the bottom of the case. Four lugs are cast on the core-case, two of which fetch up against the cushioned lugs on the composition case when the core is drawn up into the solenoid coil. The other two lugs serve as guides for the guide rods.

When the circuit is closed by the circuit closer, the current flows through the solenoid coil, exerting a strong pull on the core and its case; there being no escape for the air in the air chamber of the cylinder, except through the whistle, it gives a shrill sound. When the circuit is broken by the circuit closer, the coil releases its pull and the core and case drop upon the two spiral springs and rubber cushion. At this time the circuit closer again closes the circuit and the whistle is made to sound as before, this reciprocating action, lasting for about 35 seconds, gives a succession of short, sharp whistles.

Adjusting screws are placed on the rocker arm of the escapement which control the speed of unwinding of the main spring; increasing the distance between screws, makes the apparatus work more slowly, and vice versa.

To give an alarm, depress the lever (on the outside of the circuit closer) as far as it will go and then release it. This winds up the main spring (requiring a period of about 35 seconds in unwinding) making and breaking the circuit repeatedly.

Keep the contacts of the circuit closer properly adjusted.

Inspect fuses in the solenoid to see that none have burned out.

Keep the core-case clean; if it becomes oxidized it will not work freely in the outer cylinder.

If a ground occurs it will likely be caused by the breaking down of the insulation of the solenoid coils. To locate this, disconnect the terminals of each solenoid in succession and test out until the ground is found.

See that the switch handle always returns to its initial position, otherwise the circuit may be left closed and burn out the solenoid coils; such a case has occurred.

The signals are installed in parallel.

Owing to the liability of burning out the coils in the signals when the contact remains closed, after the clock-work has run down, a deck fixture is installed in the dynamo-room in which is a 16-candle-power lamp coated with a red lacquer. This gives a visual indicaton of the fact that the circuit is still closed.

Night Signal Set.

The object of the night signal set is to provide a device which will rapidly and accurately transmit, from one station on shipboard to another distant station, by means of lights, a prearranged code of signals, when darkness prevents other means of visual signalling. The classes of service on which the method is employed is in signalling from one vessel to another, for squadron or fleet maneuvers and for communication between vessels and cooperating military commands on shore.

Three types are in use: Two types of the General Electric Company, and the "Telephotos," the design of the Boughton Company; the present difference is mainly in the keyboard.

Either type of set consists of four essential parts: *A keyboard*, by which the connections for the individual signals are made; *a cable*, connecting the keyboard contacts to the separate lamps of the lanterns; *four double lanterns*, the upper half of which is red and the lower half white; and *a lamp ladder*, on which the lanterns are suspended and which suspends the principal weight of the lanterns and cables to an outrigger on the mast. The cables and lamp ladders for both types of night signal sets are now the same and the cables are of the type described under standard wire.

The lamp ladders are of the construction shown in Fig. 268 for the original telephotos type. At the top and bottom are two composition spreaders into whose ends are spliced two wire ropes, of seven No. 12 B. & S. G. galvanized iron wire, ¼-inch diameter. The center of the upper of these spreaders is to be attached to the outrigger by a shackle; to the lower is shackled a jumper, of the same wire rope as is used for the sides of the ladder, if the ladder can be seized to a backstay, or up to ¾ inch if all is set flying; the jumper is set up by a turnbuckle to the channels, to the ship's side, or to a deck plate, to steady the ladder assembly from swinging about in the wind, or from motion of the ship.

The spreaders for suspending the lanterns are of composition

with a score in their T-shaped ends into which the side rope is seized with copper seizings and soldered. These spreaders go in pairs and are spaced a sufficient distance to secure the lanterns by chains to their middle eye, a small amount of slack being allowed in the bottom chain that the lantern may assume a normally perpendicular position. The distances between centers of lanterns is standardized at 12 feet, but 8-foot and 10-foot distances are common; the governing rule is that the upper lantern should show below the signal yard and the lower above the top of the

FIG. 269.—Keyboard, semi-circular type, General Electric Company.

smoke pipe; when the height of the mast permits, the upper lantern may show above the signal yard and the second below it. The spacing between the lamps should be as near the standard 12 feet as the particular ship's design will admit in order to distinctly separate the lights when viewed from a distance.

The outrigger is of wrought iron and is clamped to the mast to set at an angle of 45 degrees abaft the athwartship plane, to starboard, whether installed on the fore, or on the main (or mizzen) when two night signal sets are furnished flagships. For the method of securing the cable wires to the coupling: Eight wires

are soldered together and connected with the inside (common return) socket pin of the coupling, the remaining eight being connected to the remaining eight pins; a slot on the coupling engages a lug on the socket of the keyboard to ensure proper assemblage.

Keyboard, General Electric Company, Semi-circular Type.—The keyboard (Fig. 269) consists of a water-tight box, of semi-circular cross-section, containing the contact-making mechanism. The edge of the top plate is marked for 30 lamp indications and 56 interpretations, the indications being shown as red and white countersunk and filled dots in consonance with the lights to be shown in the lanterns, below are marked the interpretations as a convenient guide. On the back are two receptacles for 25-ampere attachment plugs, and a female coupling which connects by spring contacts with the eight peripheral contact plates of the coupling (shown) and a central pin which enters the socket connections for the common return of the coupling.

The keyboard is illuminated by a 16-candle-power lamp supported on a goose-neck.

The interior mechanism, Fig. 269, consists of eight ⅛-inch cast composition contact plates, secured to the top plate by three stud bolts, the contact plates being insulated from each other by pieces of 1⅛-inch O. S. D. rubber tubing to space the plates three-eighths of an inch; the plates are assembled on the assembling bolts by nuts which are insulated by hard rubber washers. The inner edges of the plates are so fitted with hard rubber sections as to break and make contact for the lantern lamps desired.

The necessary contacts are made by a rotating stud (Fig. 269) containing eight plungers working against internal springs which keep the plungers in continual contact with the inner periphery of the plates, making electrical contact or not accordingly as the plunger is opposite a metal or insulated section. The shaft of the rotating stud is secured by an insulated guide bracket secured to each of the assembling bolts, and extends water-tight and insulated up through the top plate where the operating handle is secured by clamps.

The revolving stud is supplied with a single-pole, horizontal knife switch which is insulated from the stud, and by means of the small handle on the keyboard (shown on top of the revolving stud shaft) pulsates the indication of the upper lantern whch may be in circuit at the time.

The operating arm consists of a casting with a removable cover on the under side. A single-pole, vertical knife switch secured to the opposite side of the revolving stud, but insulated from it, operates all the lamps, and is operated by a lever within the arm which is raised, and connection made by spring action, when the knob of the operating handle is down, and is depressed by a lug on the operating handle when the knob is up. A cam lug on the operating handle engages a slot on the top plate, so that the arm cannot move, and locks the handle at the desired signal; bevelling

FIG. 270.—Telephotos keyboard and inner cover.

the edge of the cam and slots will increase the speed of signalling. When the operating handle is in a vertical position the cam lock is disengaged, and the arm can be moved to any other indication, the pointer at the end registering with the center of the signal to be made.

Current is supplied from the signal circuit to a 25-ampere switch and receptacle, and from thence to the keyboard by two conductors, fitted at each end with a 25-ampere, water-tight attachment plug.

With current switched on the circuit, as shown by the illuminating lamp, the various combinations represented by the dial are made to appear by moving the operating handle to the indication, depressing the handle and making connection through to the proper lamps in the four lanterns; by then operating the pulsating lever the lights in the upper lantern are pulsated. For instance: With the operating handle vertical, move the arm until the pointer is at the center of the desired signal; depress the handle, thereby closing the circuit through the knife switch on the back of the revolving stud; the current flows from the switchboard feeder, by way of the transfer switch to the signal circuit and by the switch and receptacle to one of the line receptacles on the key board; thence to the contact rings; to the vertical knife switch; to plungers (as affected by insulating plates); to the contact plates; to the cable by outer coupling contacts; to lamps in lanterns; back to the cable; to central contact in coupling and then through the line connection to the signal circuit, etc.

Gaskets should be inspected and renewed when the rubber hardens from long compression or partially vulcanizes from the heat of the metal, especially in tropical climates. The cable should be occasionally painted with a waterproof preservative compound.

The keyboard is usually supplied with a sheet-brass cover with conical top in which is a door for access.

When not in use this door should be kept closed, and the cover be protected against weather by a canvas hood.

The Telephotos Keyboard.—The device (Figs. 268 and 270) consists of a cast composition box, with an inclined cover so designed as to exclude water when not in use; the upper plate on the inside is packed water-tight in case of exposure. The interior is illuminated by a 5-candle-power lamp mounted on a goose-neck, the connections being paralleled across the entering leads. The standard coupling and line receptacles are the same as for the General Electric Company keyboard (although earlier forms are still in service) and are mounted on the back of the case. The cable connections as far as the coupling, coupling receptacle and lanterns are concerned are shown in Fig. 269.

The cover plate within the box is a composition casting pierced for the fitting of 31 hard rubber bushings which form the guides for the shanks of the stops. There are 31 stops, each consisting of a copper rod to which is fitted a hard rubber cap; the stops

give 30 lamp connections for a total of the standard 56 interpretations, one stop being the pulsator connection. The shank of the stop is fitted with a shoulder which takes against and depresses one of the 30 contact levers.

The levers are hinged at the back of the box, the hinges having a spring which keeps the lever out of contact with the eight wires shown, and which are strung across the box and secured over insulation at either side; each wire is connected to one of the spring contacts in the coupling receptacle. Beyond the shoulder the shank of the stop is extended to operate the locking device; this device consists of a V-shaped trough of metal extending across the box under the centers of the stops, the curve being at one side. In the trough are placed a number of nickel-plated, composition balls, only sufficient play being given to admit of the passage of one stop shank between two contiguous balls; hence when a stop is pushed the balls are moved under the shanks of all other stops and effectually prevents two displays at the same time; the interval and pulsating stops are independent of the locking device.

The levers (Fig. 270) are designed with lugs to connect only to those wires (strung across the box) as will bring into circuit the necessary lantern lamps, and the wires and lugs are tipped with platinum against arcing.

Pulsating is accomplished by leading the two connections for the upper lamp of the upper lantern through a make and break switch (shown) contact being broken on depressing the stop. Current is supplied from the signal circuit to a 25-ampere switch-and-receptable from which double conductors connect to the keyboard box and to the rod on which the levers hinge, through the levers to the box wires, to the lamp connections at the coupling, to the lamps, back by the common return to the center connection of the coupling and its receptacle and thence to the other 25-ampere line receptacle, the 25-ampere switch and receptacle, submain, transfer switch and feeder line to the switchboard.

This type of keyboard is ordinarily mounted on a pedestal, in that case the line wires come up through the pedestal.

The availability of keyboards in general depends mainly on their adaptability for signal speed; the speed is limited to the condition that the glow of one signal shall cease before the next signal is made.

General Electric Company's Keyboard, Latest Type.—This keyboard, whose mechanism as removed from the enclosing case is shown in Fig. 271, very much resembles the telephotos type. The plunger system and balls to prevent coincident signals is the same, but each plunger is made to connect to the eight busbars by wire connections to a system of spring contacts, current being afforded to the eight circuits through the springs by dynamo potential by the contacts of the plungers.

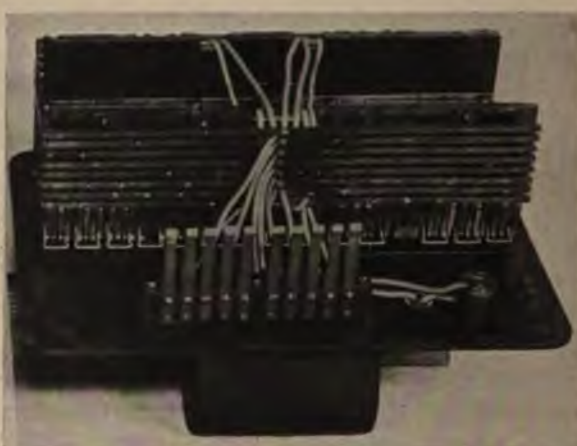


FIG. 271.—Interior of General Electric Company's keyboard, latest type.

In a modification of this device the Mustin warming-up principle is incorporated. By this principle a flow of current is continually kept up in the busbar circuits, a resistance being inserted and of sufficient amount to keep the potential below that which would cause the lamps to glow; as a result of the arrangement the time necessary to warm up the lamps—and an appreciable time—is saved, and when the lamps are switched off they cease to glow in a much shorter time; hence, the glow being cut off and caused quicker, the speed of signalling can be materially increased; and this proves successful in practice.

General Alarms.

The type most installed is that shown in Fig. 272.

The gong is 12-inch, and is struck by a clapper, operated by a clock-work mechanism, which is released by an electromagnet, and

controlled by a push button. The gong is of the single-stroke type.

The clock-work is of a heavy design, and all practicable parts are nickle-plated, to prevent corrosion. The specified operation is to strike once every half second for not less than 30 seconds, with capacity for one repetition. The release of the mechanism is to be complete on one pressure of the push button.

The push button for closing the circuit is of the usual W. T. and N. W. T. type, according to location, but is protected by a cover requiring removal before operating in order that no false alarms may be sent.

FIG. 272.—General alarm gong.

The results of tests as to the volts and amperes to operate a single gong on various lengths of circuit are as follows:

LINE IN CIRCUIT. Feet.		Ohms. Res. Total.	MIN. GOOD OPERATING. Volts.			Amps.
Length.	Run.		Gong.	Line.	Total.	
0	0	0	1.290	0	1.29	.216
100	50	.463	1.371	.109	1.48	.235
200	100	.868	1.383	.207	1.59	.238
300	150	1.275	1.403	.307	1.71	.241
400	200	1.689	1.413	.407	1.82	.241
600	300	2.523	1.361	.581	1.95	.230
800	400	3.338	1.405	.785	2.19	.235
1000	500	4.179	1.382	.978	2.36	.234
Average						.234
Strokes for each winding						175

The resistance of the coils is 5.64 ohms.

The line consists of 50 feet of 20 conductor interior communication cable connected non-inductively to represent 1000 feet of line resistance.

In the test each release was made when the gong was fully wound and three releases gave sixty strokes each to full winding.

The contact maker consists of a contact lever, normally held off from the contact ring by a spring, so that in operation the contact is made by the natural pressure of the hand.

By rotating at a natural rate the contact with the ring is closed and the current is applied to the gongs.

The gongs when installed are divided into two sections.

Turret Hoist-and-Ready and Ammunition-Car-Position Indicator.

This device is described on page 613.

Whistle Operator.

The principle of operation of this apparatus is to afford an automatic or at will method of electrically operating a specially constructed valve controlling the admission of steam to the steam whistle.

The valve and operating case is installed in the steam-pipe connection to the whistle and the electric operation is independent of the hand pull which is connected to a lever usually marked "Emergency Hand Pull." The main valve is of a special globe type and arranged to be kept normally shut by the pressure of steam or to be reclosed by such pressure when forced open; it is independent of the auxiliary valve for hand control. The stem of the valve extends up and out through the casing. The magnet case contains two multiple-wound electromagnets, over which is a heavy armature operating against a spring, and carrying a hollow sleeve on a guide post. The sleeve ends in the solid rod working through a stuffing box in the bottom of the operating case.

When the magnets are energized the armature is attracted and, pushing down the sleeve and consequently the rod, comes in contact with the valve stem of the auxiliary valve admitting steam to the whistle. When the current is cut off, the valve closes automatically under the unbalanced pressure of steam.

The connections are shown in Fig. 273. There are two places of control; an automatic and at will control in a brass, locked

operating case, usually located in the chart house; and a three-way automatic and at-will switch, with lever, usually located conveniently on the bridge.

The Mechanism of the Operating Case.—The case contains (Fig. 273):

First, a clock (indicated by the arrows) with a rotary make-and-break circuit switch; making the circuit at intervals of 54 seconds and continuing the contact for six seconds, thus giving a continuous blast of the whistle for that interval. This automatic

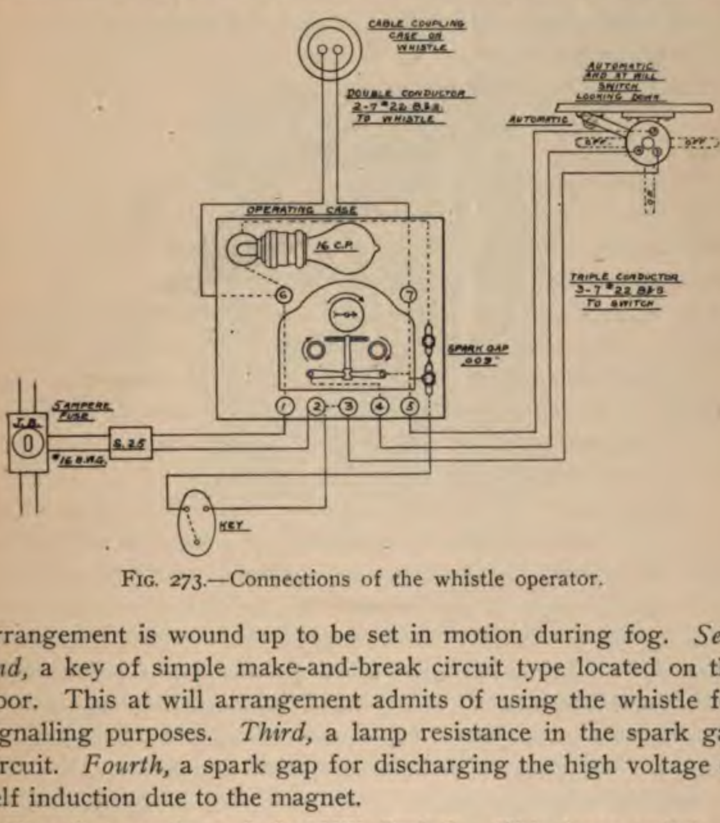


FIG. 273.—Connections of the whistle operator.

arrangement is wound up to be set in motion during fog. *Second,* a key of simple make-and-break circuit type located on the door. This at will arrangement admits of using the whistle for signalling purposes. *Third,* a lamp resistance in the spark gap circuit. *Fourth,* a spark gap for discharging the high voltage of self induction due to the magnet.

The Automatic and At-Will Switch.—This lever switch of special construction is so designed that it can be used to start the clock mechanism and thus engage the automatic, or take the place of the key in the operating case for signal use.

Tracing the connections of Fig. 273 from the junction box

and switch: First, the positive (lower) leg leads to binding post then to the key, to one contact of the spark gap, to (to the left) the connection through to the cable coupling case and back to the line; or second, from the bridge switch by the bridge switch to the operating case and through to the cable coupling and back to line; or third, from the operating case to the bridge switch through the bridge switch back to the operating case to a special contact which is connected to the rotary switch of the clock mechanism and out to the cable coupling and back to line.

There are, therefore, three individual operating circuits in parallel of which two are at-will and one is automatic.

The bridge switch shows by its name plate which way the lever is to be moved to ensure proper operation.

Telephones.

The most successful types that have been installed are those of the American Bell Telephone Company and mainly for the reason that the "solid-back" button style of microphone does not harden so readily and thereby influence the action.

For various uses five forms have been designed and of which three are still in use: Number 1, having a large wooden case enclosing the bell and similar to the type usual in commercial use; Number 4, having a small wooden case; Number 5, similar in external appearance to Number 4, and shown in Fig. 274; the last has been installed in the greatest number.

The transmitter of the Bell telephone, common in its speaking details in all forms, is shown in Fig. 275, the separate parts being shown at the side. This instrument is capable of standing a very heavy current without heating and the tendency of the granules of carbon in the button to settle down into a compact mass, commonly called "packing," is greatly diminished. *Even with so efficient a microphone as this button used with the Bell designs, packing is very likely to occur as a result of gun-shock and the telephone become unreliable;* less efficient designs can therefore be expected to fare worse.

Referring to Fig. 275, *F* is the front piece of the transmitter case and is held in the hollow case *C*, the two pieces forming a complete metallic casing for the working parts of the instrument. The sound-receiving diaphragm *D* is encased in a soft rubber ring *e* and is held in place by two damping springs *ff*. *W* is a heavy

metallic block hollowed out to form a casing for the electrodes; the inner circumferential walls of this block are lined with a strip of paper *i*. This block is mounted on a supporting rod *P* secured at its end to the outer casing of the transmitter. The back electrode *B*, of carbon, is secured to the face of the metallic piece *A* which is screw-threaded into the block *W*. *E* is the front electrode, also of carbon, carried on the face of the metallic piece *b*. On the enlarged screw-threaded portion *p* of the piece *b* is slipped a mica washer *m* held in place by a nut *u*. This washer is of sufficient diameter to completely cover the cavity in the block *W*, when the electrode is in place. After the required amount of

FIG. 274.—Bell telephone, No. 5.

granular carbon has been put into the cavity and the front electrode put in carbon the cap *c* is screwed in its place on the block *W* and binds the mica washer *m* firmly against the face of the block *B*, thus confining the granules in their place. The electrodes are of somewhat less diameter than the paper-lined interior of the block *W*, so that there is a considerable space around the periphery of the former, which is filled with carbon granules; this prevents the binding of the free electrode against the edge of its containing chamber, and also allows room for the granules which are directly between the electrodes to expand when heated by the passage of current. The screw-threaded portion *p* of the piece *b* passes through a hole in the center of the diaphragm, and is clamped

firmly in place by the two nuts *tt*. *M* is the mouth-piece of hard rubber, screw-threaded in an opening in the front block *F*. Any vibration of the diaphragm is transmitted directly to the front electrode *E* which is allowed to vibrate by the elasticity of the

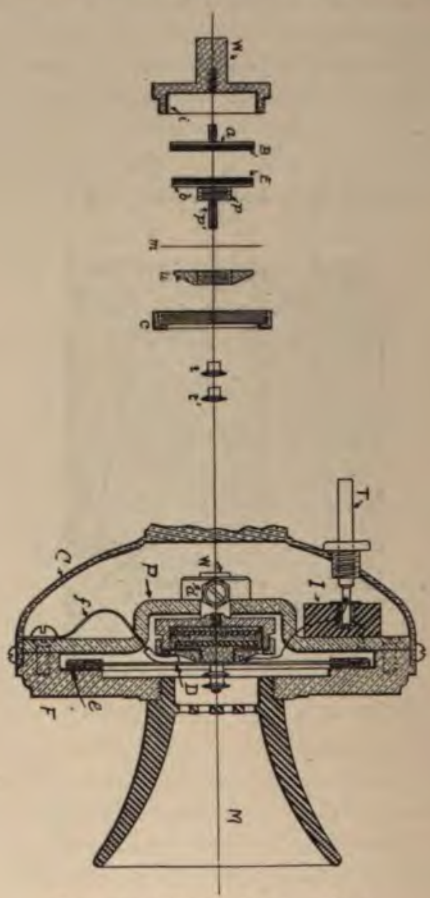


FIG. 275.—The Bell transmitter.

mica washer *m*. The back electrode is stationary, being firmly held by the bridge rod *P*.

For large installations the practice on many ships has been to connect the telephones up on a common talking circuit, with a separate ringing circuit. The limitations of the number of simultaneous conversations in the form of connection, are now over-

come on the large vessels by a switchboard, with an operator constantly in attendance who can move the connections for a number of separate and simultaneous conversations up to seven or nine. The extra cost and weight of the ringing circuits are eliminated by utilizing a plan of corrections similar to that in large city exchanges where it is only necessary to lift the receiver from the hooks to call up central. The same lines of commercial practice are followed in the use of lamp indicators at the central station

FIG. 276.—Cory type of telephone.

with a talking and ringing current from specially constructed motor generators.

The Cory Type of Telephone.—A device commonly installed of late is the Cory telephone shown in Fig. 276. Its main features are the double-ear tubes with rubber pads, the idea being to protect the ears from extraneous noises.

In a later device an arrangement is added by which the diaphragm can be tapped to counteract packing of the button.

The receivers used are not essentially different from those or-

dinarily used with commercial telephones, whether of the long or watch-case variety; or when self-contained.

The Time-Firing Device or Stoking Indicator.

There are three varieties of this type of apparatus which differ in so many important details that only one will be described as giving a general idea of the intent of all.

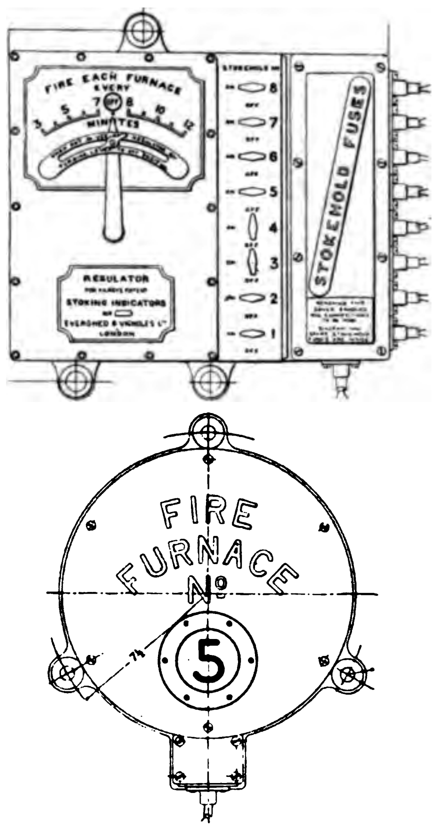


FIG. 277.—Diagram of face of regulator and indicator of Kilroy time firing device.

The Kilroy Device.—The apparatus has been devised for the purpose of facilitating uniform firing of boilers and thus to secure a maximum coal efficiency and a minimum of smoke production. To carry out the intention of the device it is necessary to mark each furnace door with a brass number as painted or chalk figures

are too easily obliterated. An indicator is placed in each fire-room and is constructed to show the number of the furnace which is to be fired next in definite rotation and at the same time ring a loud gong to attract attention; all indicators are actuated electrically by one regulator or transmitter placed in one of the engine rooms.

The regulator, transmitter, or timing apparatus consists of a

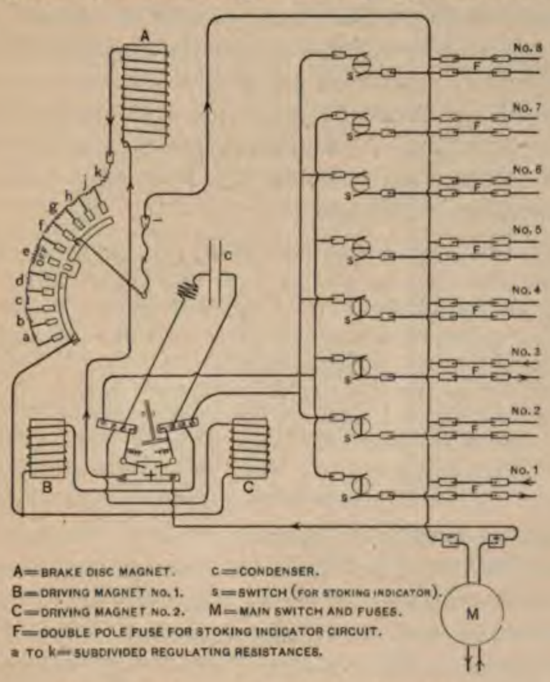


FIG. 278.—Connection of time-firing device.

special switch mechanism which closes electrical circuits at uniformly recurring intervals of time and these recurring closures actuate the indicators, the switch mechanism being so designed that the fire-room indicators do not all ring simultaneously, the arrangement being that the minimum number of furnace doors shall be open at one time. A regulating lever is provided to enable the engineer in charge to vary the rate of firing at will; the lever over the scale marked "firing interval in minutes" being movable, and the designed firing interval being the time in minutes between two successive appearances of the same number on the indicator

and hence the interval between two successive firings of the same furnace; for example, let the regulator be set for eight minutes' interval, then the time between two successive appearances of the same number on the indicator will be eight minutes and in this period a complete rotation of numbers will have occurred; if the fire-room indicators show numbers from 1 to 8 (corresponding to a similar number of furnace doors) each fire-room will show a new number and ring a bell once a minute, and so on. A set of switches is provided, one for each indicator, so that only those indicators which are necessary need be switched into circuit. When once switched into circuit the apparatus works automatically and requires no attention. A diagram of the faces of the regulator and of the indicator are shown in Fig. 277, and the general electrical connections in Fig. 278.

[NOTE 31.—As a rough rule for determining the quantity of coal required at each firing, the following may be taken as a typical case: Assuming that each boiler is to be worked at an output of 450 h. p. and that the coal consumption is 2 lbs. per i. h. p. hour, then the coal burnt per boiler will be 900 lbs. per hour; and (taking the weight of a shovelful of coal as 10 lbs.) this will be 90 shovelfuls in 60 minutes for each boiler. If eight minutes has been decided upon as the firing interval, the number of shovelfuls required for firing each boiler during that interval will be 12. If each boiler has four furnaces this will mean three shovelfuls in each furnace door every time its corresponding number appears on the indicator.]

Circuits are led off from a lighting circuit to the combined main switch and fuses *M* (Fig. 278), the path of the current being from the positive terminal of the regulator, through the automatic switch, to either one of the driving magnets *B* or *C*, and so to the negative terminal. The electromagnets act alternately upon a pivoted soft iron armature which communicates its motion through gear wheels to a plain copper disc, and this disc, rotating in the field of another electric magnet, acts as a Foucault or eddy current brake. The winding of the brake magnet and its variable resistance form with the winding of the driving magnet two parallel circuits across the total potential in order that the relation between the pull on the soft iron armature by the driving magnet and the retarding force on the copper disc any action of the brake magnet field may remain practically independent of changes of voltage.

The two driving magnets are arranged symmetrically about the axis of the soft iron armature, and but one is energized at the

same time. The automatic switch, depending for its action on the motion of the soft iron armature, serves to break the circuit of one magnet and make that of the other when the armature has moved in one direction or the other to the end of its swing; this motion of the armature—first one way and then the other—and the consequent similar rotations of the brake disc are continuous and automatic as long as the apparatus is switched on.

The automatic switch, besides directing the current to the driving magnets switches off and on at the same time the circuits to the fire-room, and the indicators are actuated at each reversal of the regulating armature. The time between successive reversals is determined by the position of the lever on the face of the regulator which is mechanically coupled to an inner contact arm which in turn varies the resistances shown and which are in series with the brake magnet. The resistances are wound with wire of constant temperature coefficient.

Upon the armature spindle of the automatic switch is mounted a small disc, having at its periphery a discontinuous guard flange in two parts and also an arm-piece, all of which oscillate with the soft iron armature. To the ends of the arm-piece are fixed two spiral springs connected at their other ends to two points one on each side of the axis of the switch. The upper end of the switch terminates in a fork which is itself clear of the disc, but each end of the fork has a projecting pin which engages against the outside of one of the flange guards. When the armature has completed part of its oscillatory travel, the springs tend to make the automatic switch pass over to its other oblique position, but a pin prevents its movement until the armature has completed its stroke; the tension of one of the springs then sharply brings over the automatic switch to its alternative position, when the contacts on one side are let down and the contacts on the other side are broken, and thus the motion is reversed.

A condenser (Fig. 278) with a resistance in series, is connected across the brake to overcome the spark which can be considerable on account of the induction in the broken circuits.

Each indicator consists of an outer case protecting the bell; this is mounted in an inner water-tight case which also contains the mechanism for moving the dial marked for the numbers of the furnace doors. When the current is on and the soft iron magnet is magnetized, an armature is attracted and a single stroke

rung on the bell. An inner armature then acts on a cup wheel and drives the wheel one step to the next indication of the dial, and both armatures return by the action of their springs without changing the number shown and are set ready for the next operative stroke.

Referring to the connection diagram it will be noted that when a fire-room switch is on at the regulator the corresponding indicator has current half the time only.

Notes on the Use of the Device.

To obtain accuracy when setting the "timing interval" place the regulator lever on the "off" position in the middle of the scale and then move it slowly to the desired mark.

On a 125-volt circuit the regulator takes about 0.2 ampere and each indicator about 0.1 ampere. Since the main fuses blow at about 5 amperes, larger fuse wire than that provided must not be used.

When the apparatus is not in use turn off the main switch.

Place the regulator in such a position that both covers and glands will be readily accessible, and that the regulator may not be subjected either to excessive heat or vibration. Do not remove the cover of the regulator.

The center of the indicator should not be less than 6½ feet nor more than 8½ feet above the floor plates.

The Blinker Light.

This device is used as an auxiliary means of signalling by wigwag code employing a flashing light for the purpose.

The device is shown in Fig. 279 and consists of a cylinder whose upper part is cut away to give an all-around view; for mechanical construction the three ports are separated by strips of the side of the cylinder ¾ inch in width and located on the 120-degree arcs. Covering the ports inside is a hollow cylinder whose lower end is closed and to this end is screwed a rod which extends down and out through the bottom of the outer cylinder where it is finished with an eyebolt to which attaches a line and toggle. Pulling on the toggle opens the outer ports and causes a flash, the inner cylinder being returned to cover the ports by the action of a spring under its base.

A bail with an eye permits hanging the device where convenient. A length of double conductor, plain, with water-tight attachment plug is fitted through a stuffing tube in the top, in order that convenient receptacles may be utilized. The lamp is of 32-candle-power and is set in a type-A socket.

Bridge Semaphore, 2-Arm.—The device as made thus far has been constructed in the general form of Fig. 280. The two upper

FIG. 279.—The blinker light.

FIG. 280.—Bridge semaphore, 2-arm.

arms are used as shape signals in the day time; they are also fitted with three lamps each for night use. The lower arm is a day indication for the vessel to which the signal is making, the operator having it on his right hand when facing that vessel.

At the top is a fixed red light which serves as a mark point for fixing the attention of observers when awaiting signals; this light is screened for all directions excepting that in which the signal is to be sent.

When installing on vessels in which the bridge is exposed to the blast of the 8-inch guns, the opening of the standard should be inboard to facilitate unshipping when clearing ship for action.

On some vessels it has been found advisable to install on the boat cranes.

The arms are operated independently by the cranks and sprockets shown.

The Fiske 4-Arm or Masthead Semaphore, or Day-Signalling Device.—This apparatus is a shape-signalling device supplementing the night-signalling set for day use.

FIG. 281.—Keyboard (left) and double solenoids of Fiske day-signalling device.

The shapes are four light vanes set on shafts from band clamps on the masts and which can be moved to an angle of 45 degrees, to the horizontal or back to a normal vertical position, corresponding to the red, white and out indications of the night-signalling set, or to the 1, 2 and 3 positions of the wigwag code. The vanes are center pivoted (a feature which gives best working conditions under wind pressure) and are moved by a simple lever at-

tachment on their rear side with a stop to prevent motion beyond the horizontal position; the vertical, or off position is regained under the action of springs. The actuating force of the vanes is a set of four double solenoids located in the fore or upper top, to the spindle of whose plungers is attached a wire rope which leads to the lever on the vane and which has two legs at the solenoid end (Fig. 281); any slack of the rope is taken up by turnbuckles. The double solenoid is necessary for the two positions which each vane is to assume, one actuating to the 45-degree position and the other drawing the plunger still farther until the vane is in the horizontal position and brings up against the stop.

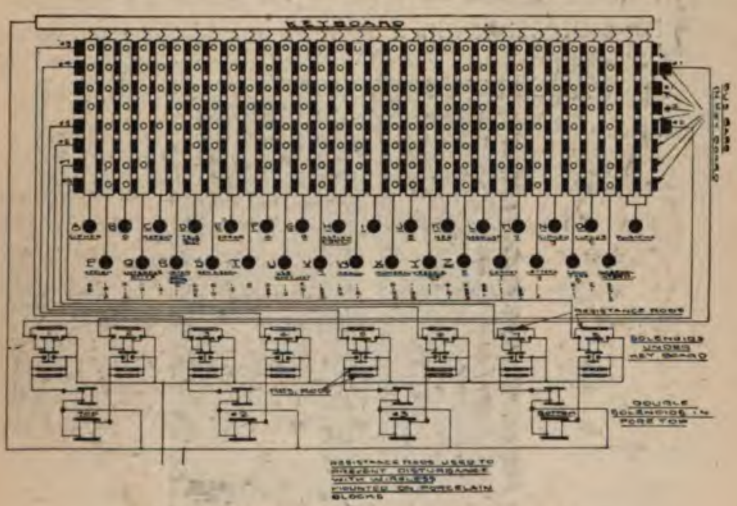


FIG. 282.—Connections Fiske day-signalling device.

The keyboard is shown in Fig. 281, left. It has the same number of keys (31) as that for the telephotos (Fig. 270) and these make connection to the eight solenoids shown in the base by a lever system whose principle is in general similar. The rods of the plungers of these eight solenoids close the contacts of the eight circuits to the four actuating solenoids in the foretop, the contacts being of carbon on account of the heavy sparking from induction; four of the keyboard solenoids connect with the upper of the double solenoids, while the other four make connection with both the upper and lower of each double solenoid and in series as shown in the connection diagram (Fig. 282); hence one

set of four solenoids serves to turn the vanes to the 45-degree position while the other four accomplish the horizontal and therefore any combination of the three positions for separate vanes is possible by a suitable arrangement of the key contacts.

A more convenient method for signalling is to install two sets of vanes, one set looking fore and aft and the other athwartships; with this arrangement both sets work simultaneously, one set is operated by the double solenoids and the other through gears from the first.

The heavy sparking of the keyboard solenoid contacts together with their location on the after bridge is found to interfere with the reception of wireless messages; this can be remedied by shunting each contact with a high carbon resistance and reducing

FIG. 283.—Indicator for electric log.

the effects of induction by installing part of the cable leading to the double solenoids in conduit; the conduit must of course be grounded, but this will usually be the case when attached to bare metal.

Electric Log Indicator.

The object of this device is to give in the Chart House, without resource to passing the word along the deck, the readings of the log and also to show a totalled record.

The Transmitter.—This consists of the usual log indicator modified to make and break an electric circuit. It is mounted on

a bracket which clamps to an awning stanchion and extends outboard horizontally. At the outer end of the bracket a hole is drilled vertically for the pivot of the trunnion yoke and a screw at right angles engages in the groove of the yoke to prevent running out. On the second gear is mounted a Tobin bronze cam insulated from the spindle by a hard rubber bushing, but turning with the spindle to which it is firmly secured by means of a hard rubber key. The cam makes one turn for every 88.2 turns of the rotator, or at the speed of one knot per hour it makes one-sixth of a turn per minute. The contact device consists of a rigid contact and a spring contact mounted on a hard rubber block which is secured to the case of transmitter. On top of spring is fixed a boss

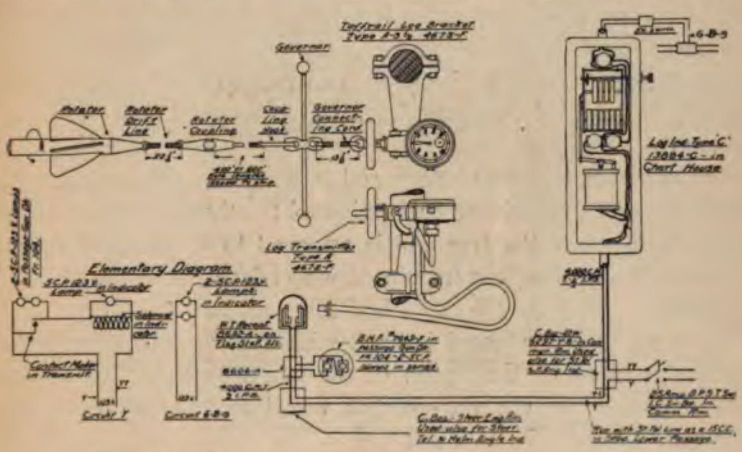


FIG. 284.—Connections of electric log (*Connecticut*).

adapted to be engaged by the cam on the spindle. The boss is so shaped that when the cam releases, the contact arm can snap up and make a quick break in the circuit.

To prevent the damage that might ensue if the log were from any reason turned in the wrong direction the worm wheel is mounted loosely upon its spindle and is driven by a pawl which will release when the direction of rotation is reversed. The contacts are made by two circular brass discs, each having an annular groove in which a platinum wire is set. These discs can be loosened up if sparking has made it desirable and a new portion of the platinum put in position to supply the contact surfaces. The amounts of surface furnished at the discs will admit of a long

period of service with shifting, as found necessary. Two 5-candle-power lamps connected in series are shunted across the contact maker to reduce sparking to a minimum. If the transmitter from any cause becomes inoperative the lamp in the indicator will either remain permanently lit or cease to glow at regular intervals. In either case the stopping of the instrument would soon become noticeable.

The Log Indicator (Fig. 283).—The log indicator is located in the chart house and is a counter which is actuated by a plunger in a solenoid. The readings on counter indicate tenth of knots on the right-hand figure and knots on left-hand figures. The readings on the dials of the transmitter are unchanged and readings can be taken there independently whether the electric counter is working or not. The solenoid is inclosed in an ironclad frame with a hollow core. The ironclad construction is adopted to prevent the leakage of magnetic lines which would affect the compass in the vicinity.

The upper end of the plunger rod is attached to the center of a lever; one end of the lever being pivoted to a lug on the frame of the solenoid while the free end is attached to a rod carrying an escapement operating a star-pointed wheel fastened to the counter mechanism.

The bore of the solenoid is lined with a brass tube in which a plunger is lifted by the action of the magnetic field; lifting the escapement moves the star-pointed wheel and the counters are revolved.

There are three 5-candle-power 123 volt lamps installed inside the case. Two of these are connected directly to the lighting mains and are used to illuminate the dials. The other lamp shunts the solenoid and is used as an indicator and glows when current passes through the solenoid.

All contacts must be kept clean. The ball bearings, gear train bearings, cam surfaces, and pawl driven worm wheel should be oiled. The escapement in the indicator should be oiled before using. The circuit is on the dynamo potential taken from the interior communication panel in the central station.

A diagram of the connections is shown in Fig. 284.

CHAPTER XV.

NOTES ON INSTALLATION.

Preliminary Considerations.

The initial factor in determining a scheme of installation is *the voltage,* for upon this depends the construction of many devices, especially the power apparatus. The present standard is 125 volts; many ships have 80 volts, and auxiliaries have commonly 110 volts.

The second consideration is what may be termed the *method of installing;* that is, whether the method shall be for molding, conduit or insulator, or a combination of two or all.

[NOTE 32.—As to a system, the two-wire has been the invariable practice; three-wire work is installed in the *Kearsarge* and *Kentucky* but only in connection with the speed of certain motors whose supply lines, being also fed two-wire for the lower voltage, constitutes rather a five-wire supply for the multivoltage (80 and 160 volts) plan than a three-wire system as commonly accepted.

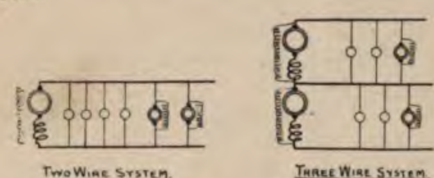


FIG. 285.—Illustrating two-wire and three-wire systems.

The commercial advantages of the three-wire system are two—an important saving of copper in the leads, and the availability of two voltages for motor speed. These can be explained in the following example:

Referring to Fig. 285, left, the dynamo is supplying (omitting the motor) four lamps on the two-wire system and taking ½ ampere each at an average distance L and maintaining a potential of 100 volts at the lamps; hence each lamp takes 50 watts, and the four lamps, 200 watts. The circuit must evidently carry two amperes. From the formula for wire size (page 594), and allowing three per cent drop, the circular mills

$$= \frac{2 \times L \times 2 \times 10.87}{3} \qquad (1)$$

The two dynamos of Fig. 285 right, are connected in series on their inside poles and from this connection the middle wire (or "neutral") is

run. They are feeding their outside wires from the positive pole of one dynamo and the negative of the other. The four lamps are shown connected from the outside wires to the neutral, the neutral acting as positive to the two lower lamps and as negative to the two upper. The arrangement may be regarded as two sets of two lamps in parallel, the two lamps of each set being in series. Since the potential of the two outside wires is double that of either dynamo taken singly, the potential at the lamp terminals of each series is 200 volts; and, as each series requires but ½ ampere the expended energy for the system (omitting the motor) is 200 watts; the current, however, will be but *one ampere*. From this it is evident that the current required for the three-wire system is but half that required for the two-wire. Again the drop for the double potential can be twice that for the single and the circular mills

$$\frac{2 \times 2L \times 10.83}{2 \times 3} \qquad (2)$$

Comparing (1) and (2) it is seen that the wire size in circular mils necessary for the three-wire system is but *one-fourth of that for the two wire*. Calculating this for saving in copper for the three-wire, as compared with the two-wire for the lower voltage, the saving will be in the ratio of 1½ : 2, a saving of copper of 62½ per cent; or, following the common custom of making the neutral wire one-half the size of the outside wires, the saving will be in the ratio of 1⅜ : 2, a saving of 68¾ per cent. This saving, though in somewhat lower percentages in practice, is an important economical consideration in commercial line constructions where the distances of transmission are great.

The motor in the two-wire diagram evidently receives one-half the terminal potential of that in the three-wire, hence its speed is approximately halved without rheostatic loss.

The copper saving and speed considerations are outweighed in man-of-war installations, because *first*, the life of the wire is somewhat reduced; *second*, the lines of wiring are materially short in comparison; *third*, it is found that it is not necessary to resort to multivoltage control of speed, that is, great ranges are not required; *fourth*, the system necessitates the use of two dynamos at the same time; *fifth*, the multivoltage plan requires five wires instead of three and there is really increased cost instead of saving.]

The method of installing is dependent upon the nature of the duct to be employed; the line of appliances, etc., being different for molding, insulators and conduit. Experience lays down the following rules as to a selection.

I. The best method is a complete conduit installation throughout the ship.

II. As a consideration of the saving of weight in the ship's construction insulators may be used in certain locations where water-tightness is not necessary, or mechanical injury to the wiring is not likely.

play.

REMARKS.

III. Any combination of conduit and molding or insulators for economical reasons is usually restricted to the plan of using conduit exclusively in the following locations (molding or insulators may be used in other locations):

1. All locations below the protective deck.
2. All exposed leads on decks open to the weather.
3. Galleys, bakeries, machine shops, and evaporator rooms.
4. Drum rooms and spaces connecting with the fire- and engine-rooms.
5. Ice-machine and cold-storage rooms.
6. Wash rooms and heads.
7. All vertical runs requiring overhauling or renewal.

Determination of Generator Units and Supply.

The total supply of electrical energy, and the selection of the number and size of units, is based upon three main considerations: *First,* that the units shall be of the same size, in order that all parts may be interchangeable; *second,* that the units shall be of the largest sizes of generator which a convenient division of the output will admit; *third,* that at least one unit shall be in reserve, in excess over the total output demanded (33 per cent overload considered), that it may be kept turning over slowly and sufficiently to avoid water hammer, and be in readiness to parallel in on the load in case of accident to or failure of any other unit.

A tabulation of the various divisions of the energy, in convenient form, is first made as in the preceding table for the *Connecticut.*

In the first column is shown the various divisions of duty to which the total output is distributed. Column 2 shows the number of each type of the various divisions which are installed, those opposite the divisions for lighting being the number of lamps or outlets to be supplied. Columns 3 to 9 show the estimated ratios of the numbers in column 2 which will probably be in use when in action, or at sea or in port for day and night. Column 10 contains the kilowatts necessary for each of the numbers in column 2 which is based on kilowatt consumption. By multiplying the numbers in column 2 by the quantities of column 10, column 11 is derived, and shows the total kilowattage demanded of the source of supply were every division of supply furnished with full-rated energy; its total and details are mainly for reference.

The remaining columns are the actual demands of service use for their particular occasion, estimated on the actual requirements and probabilities of use as derived by multiplying the ratios in columns 3 to 9 by the quantities of column 11.

Columns 12 and 13 show the requirements for action in battle, or general quarters, for day and night service. Columns 14 and 15 show the ordinary demands on the plant, by day and by night, when the ship is underway. Columns 16 and 17 show the ordinary demands of the plant when the ship is at anchor, or moored to dock, and the main engines are not in use. Column 18 shows the probable demands on the plant when the ship is illuminated *en fête*. The totals of these columns (12 to 18) evidently afford a good guide as to the load to be anticipated on the several occasions, and form the basis for the determination of the number of units that will be required to be operated at the particular time.

Inspection of the totals of columns 12 to 18 develops that the greatest demand on the output for the *Connecticut* will be in night action, and that the fair probability is that 770 k. w. must be supplied at some given time; it may be that all turrets, etc., may not be in operation at the same instant, but it is wiser to provide for such a contingency, especially for time of action, however remote.

On the basis of the 770 k. w. demanded, selecting the smallest number of standard units of the same size, and assessing the operating units at 33 per cent overload (a requirement for two hours operation on acceptance and intended for more protracted operation in emergency) the *Connecticut* requires six generating sets of 100 k. w. size. As a matter of fact the ship has eight 100-k. w. size units, four in each of two dynamo-rooms widely separated in the ship. Four 200-units would be up-to-date.

Analysis of the Divisions of Load.

Lighting Locations and Installation.—The location of the individual outlets, whether for fixed or portable lights, is a matter which is quite independent of their feeders and mains, and can well be taken up first, for the reason that outlets are primarily independent in the requirements of location, and can later be assembled into submains, according to the control required for their service locations, and for keeping their energy within the limits which may be prescribed by the specifications for the mains and feeders.

Elevations Above the Deck.—To afford proper accessibility in installation, operation, repair, and distribution of light for the service required, the following distances above the deck should be used whenever practicable in installing on bulkheads, stanchions, etc.:

Switches, junction boxes, distribution boxes, switch-and-receptacles, receptacles, battle lantern brackets, portable hooks, double receptacles, desk light hooks, 5 feet; fans and fan brackets, 5½ feet; bulkhead lights (standing) to bottom of globe, 2½ feet.

Light Distribution.—The nature of the outlets on the lighting circuits (including lighting and battle circuits) and their disposition in the different locations on board ship, are usually assigned as in the following scheme for a battleship. The general requirements for any shipboard installation are practically the same, though differing in number of outlets for ships of smaller size and different type. The actual number of each type of outlet is not given, except as restricted, as the number will depend upon the class and size of ship.

Standard of Illumination.—The rule for *overhead lighting* is that at least one 16-candle-power lamp shall be installed for every 500 cubic feet of space in the following locations:

Berthing spaces.
Cabin, admiral's.
Reception room, admiral's.
Chart house.
Galleys.
Dynamo-rooms.
Fire-rooms.
Ice-machine rooms.
Sick bay.
Emergency cabins.
Blacksmith shop.
Cabin, captain's.
Reception room, captain's.
Contagious ward.
Offices.
Engine rooms.
Turret-handling rooms.
Operating rooms.
Evaporator rooms.
Cabin, chief of staff.

Uses of Fixtures and Receptacles.—The general uses of the fixed outlets for lighting purposes are:

Ceiling Fixture No. 1.—This fixture is for overhead lighting only, and its use should be restricted to the overhead lighting of the cabins for the admiral, captain and chief of staff, and any passages connected therewith; reception rooms, admiral's and captain's; the wardroom countries and passages in front of staterooms; cabin staterooms; messrooms aft.

Ceiling Fixture No. 3 is used for overhead lighting only and replaces ceiling fixture No. 1 for the following locations:

Staterooms for the admiral, captain and chief of staff; staterooms of other officers when the installation of an overhead fixture is assigned; chart houses; emergency cabins; contagious ward; offices; countries and mess rooms of junior officers and warrant officers; passages in quarters not lighted by a ceiling fixture No. 1; operating room and sick bay.

The fixture gives a larger area of reflection of light than the ceiling fixture No. 1 and greater illuminating power, especially if fitted with a clear glass globe.

Commercial Ceiling Fixture.—This type is installed in lieu of ceiling fixture No. 3 in staterooms, offices and the like when a smaller type of fixture will answer and when some overhead lighting seems advisable.

Bracket fixtures are installed for the side lighting of cabin and wardroom countries and reception rooms. They are intended also as a reading light, and the double or single type is installed as best suits the location. A single bracket is installed on each side of all sideboards.

Binnacle Light Fixture.—The two types are a part of the binnacle construction.

Turret-Hood Fixture.—This fixture is installed in the position most convenient for its use as explained in its description.

Telegraph fixture is an attachment for electric lighting of mechanical telegraphs only and is really a part of the device.

Double Receptacle.—This type of wiring appliance outlet is intended principally as a terminal for locations when a desk light and a fan are to be plugged in, as in staterooms and offices. The rule is that when a desk light and a fan are to be allowed for the location, this type of outlet is to be used. It is to replace the non-water-tight receptacles.

Deck, Bulkhead and Drop Fixture.—All overhead lighting other than that prescribed for ceiling fixtures No. 1 and No. 3 is accomplished by the deck, the bulkhead or the drop fixture.

The deck fixture is generally to be preferred, if the head room admits, as it gives a large area of illumination. It is sometimes an advantage, when the head room is great, to attach a bulkhead fixture to hang below the beam and bring the lamp lower than would be practicable with the deck fixture.

The bulkhead fixture should never be installed for overhead lighting when it will be exposed to leakage and drip of water, or when the compartment is to be subject to the access of steam; the globe will not be water-tight in such locations due to its horizontal position. If lighting is desirable on both sides of a bulkhead it should be provided by separate lights.

The drop fixture is used for overhead lighting when the available securing position of a deck fixture would be too high up for good distribution of light, and mainly in engine-rooms, fire-rooms and their connections. When the conduit connection to the drop fixture is over four feet long the fixture should be steadied by at least three stay chains or wires, four are preferable.

The bulkhead fixture is used for all side lighting (except when bracket fixtures are installed) in living or berthing spaces; and is so installed that the bottom of the globe shall be 30 inches above the level of the deck. On decks usually inhabited by the ship's crew, one bulkhead (side) light should be installed about every third frame apart to afford convenient light for reading and sewing.

Neither of the three types should ever be installed in storerooms unless the storeroom is one which is not to be locked and is to be usually occupied by a storekeeper or other person.

Switches-and-receptacles and Receptacles (5-ampere) are for attaching portables or may be used as the single outlet for a desk light or a fan.

Specific Lighting of Compartments and Locations.

The following distribution, derived from the installation of the *Connecticut* indicates the method of lighting the various compartments and locations *not already referred to,* and for the manner of lighting described.

Air Locks.—Deck fixtures if the head room admits, otherwise a bulkhead fixture overhead.

Ammunition Conveyers.—Deck or bulkhead fixtures, according to the locations available, at side or overhead. Also a switch-and-receptacle for a portable which is to be used in examination or repair of the motor and running gear; to be specially installed if one is not already located within convenient distance for some other intermittent use.

Ammunition-Hoist Motors and Hand-Operating Gear Panels.—The same as for Ammunition Conveyers.

Ammunition Passages.—Deck lights in preference to side bulkhead lights, to give a better general distribution of the light and keep the glare of the lights above the eye line.

Armory.—The same as for ammunition passages and for the same reasons.

Ash Chutes.—A deck fixture, if not already sufficiently lighted by adjacent fixtures installed for other purposes.

Ash Hoists (Upper End).—A deck fixture, if not already sufficiently lighted by adjacent fixtures installed for other purposes. Also a switch-and-receptacle for a portable, for examination of the engine at the lower end.

Bakery.—Bulkhead fixtures so located as to show inside the ovens when the doors are opened for examination.

Barber's Chair.—Deck fixtures; two or more.

Berthing Spaces.—The deck fixtures to be so located as to clear mess tables when stowed or being handled. A liberal allowance of end room is required when located between the same beams as the tables. The *minimum number of standing lights* is that necessary to assure convenient travel from one compartment to another; locating at the side of the bulkhead doors favors the desired result.

Blacksmith Shop.—Deck lights overhead, keeping clear of the forge and the swing of the sledge around the anvil; also a switch-and-receptacle for a portable.

Blowers, Ventilation.—A switch-and-receptacle with a portable permanently installed and with a portable hook; for the examination of the lubrication, etc.

Blowers, Forced Draft.—A bulkhead or drop fixture so located as to show the operation of the header from which the bearings are oiled; also a switch-and-receptacle, with a portable permanently installed, with portable hook, for general examination of the working parts.

Boats, Davit, Cradle.—For the emergency handling of the boats at night, a switch-and-receptacle for deck lanterns on each side of the ship near each boat crane, if others are not already installed for intermittent use.

Book Cases.—In quarters, ceiling fixtures No. 1 or No. 3 located to throw the light at an angle of about 45 degrees. In other

locations than quarters, deck or bulkhead fixtures similarly disposed.

Booms, Boat.—A switch-and-receptacle on each side of the ship.

Booms, Propeller.—A switch-and-receptacle for each side. On ships of low freeboard an efficient location for the outlets is at the flagstaff. An elevation of three or four feet from the deck may be obtained by running the conduit up from below for a short distance above the stuffing tube and making a short horizontal run by using a nipple with two elbows; this may be used as a hinge piece for the upper extension to the switch-and-receptacles. The switch-and-receptacles are joined together in a vertical line by short nipples and mounted to a common base which is secured to the forward side of the flagstaff with ready means of detachment. When it is desired to lower the flagstaff in clearing ship for action the switch-and-receptacles are detached and lowered; the flagstaff can then be lowered independently. It is essential that the conduit be not located in the wake of the chocks for chains and hawsers where it will be carried away. The device is comprised in a standard drawing.

Booms, Coaling.—Switch-and-receptacles in the upper decks are required from which portables may be taken to afford light in coaling at night.

The searchlights are used at times to supplement the lighting in emergency; but their use is not recommended as in the inclined position of use the heating of the mirrors is excessive.

Bridges, Lower.—No fixed lights for general lighting are installed in these locations. There are especial requirements which are described under their specific headings.

Bulletin Boards.—A deck fixture located conveniently overhead.

Carpenter Shop.—Deck fixture overhead and a switch-and-receptacle for a portable.

Chart Board.—A switch-and-receptacle for a portable fixture such as a deck or battle lantern.

Coal Bunkers.—The lighting at the doors through which the coal is carried into the fire-room is by a bunker fixture so located as to throw the light on the coal which is in the immediate vicinity of the door.

The remaining lighting is done by similar fixtures located well to the top of the bunkers, and in a line with the escape doors or deck plates of the coaling trunks and thus light the last portions

of the bunkers when trimming; and by the overhead type of fixture.

Contagion Ward.—Ceiling fixture No. 3 overhead, and a double switch-and-receptacle for portable fixtures when making examinations.

Cranes, Boat or Anchor.—For the handling of the boats or anchors at night, switch-and-receptacles for deck lanterns on each side of the ship to be near each boat crane, if not already installed for the intermittent purposes; on the forecastle, to be conveniently located for use in securing or letting go the anchor, or for lowering over the side.

Coffer Dams.—Switch-and-receptacles for portables to be used as required if not already installed for other intermittent purposes.

Conning Tower.—A switch-and-receptacle and a battle lantern bracket for the battle lantern.

Conning-Tower Tubes.—When the tube is of sufficient diameter to be used as a means of access to the conning tower from below, bulkhead fixtures should be installed.

Coal Chutes and Trunks.—In some cases it is advisable to install bunker lights in the coaling trunks to assist in examinations to avoid choking up when coaling.

Coal-Trimming Doors.—Switch-and-receptacles for portables as required, if not already installed for other intermittent purposes.

Dispensary.—A ceiling fixture No. 3 and a deck light overhead; also a double receptacle for a desk light and fan.

Distribution Boards.—Deck fixtures, if not fitted with brackets as part of the construction.

Double Bottoms.—All man-holes on the hold deck, for access to the double bottoms, should be provided with switch-and-receptacles at the nearest convenient points on the hold deck for the connection of water-tight portables and portable ventilating sets.

Fresh-Water Tanks.—Deck and bulkhead fixtures as are required for handling of the valves, and switch-and-receptacles for portables for use in examination and cleaning.

Galleys; Admiral's, Captain's, Wardroom, and Crew's.—The deck fixture is ordinarily installed as giving the best general distribution of light. The heat, steam, and smoke pipes in these locations necessitate especial care in locating.

Gangway.—Switch-and-receptacles for the attachment of cargo reflectors or deck lights, which are used in lighting the side lad-

ders, etc., are installed; they are usually located in the hammock berthing.

Guns.—Conveniently to all guns are located switch-and-receptacles, and battle lantern brackets or stands for the battle lanterns. The switch-and-receptacles are located, if practicable, back of the breech of the gun, in order that the bight of the double conductor, plain, cannot foul the feet of the gun's crew at their stations. Battle lantern stands are installed in locations where there are no stanchions or bulkheads for the convenient attachment of the switch-and-receptacle and battle lantern bracket for cage mounts.

Hammock Stowage.—The normal lighting for other purposes is sufficient for the requirements in handling the hammocks.

Hatches, Companion.—A deck light over the foot of the ladders affords the best method of lighting; the shadow cast by the lower coaming shades the eye from the direct glare of the light when coming down.

Hatches, Boiler, and Engine.—The ladders and gratings used for access to the boiler and engine rooms can be best lighted by bulkhead fixtures and should avoid throwing a direct glare of the light into the eyes.

Hold.—When fitted with permanent ladders, deck fixtures are fitted in those parts of the hold which are ordinarily free from stowage; switch-and-receptacles are installed for the attachment of portables for locating and breaking out material.

Laundry.—Owing to the steam and dampness in this compartment the appliances are all of the water-tight character; deck fixtures overhead, and switch-and-receptacles for a water-tight portable for general use and examination of the laundry machinery.

Library, Crews.—(See Book Cases, last paragraph.)

Locker, Chain.—A switch-and-receptacle for a portable, located conveniently near the hatch.

Locker, Vegetable.—These lockers, when stowed on bridges and upper decks, can ordinarily be served from other switch-and-receptacles installed near by.

Locker, Wine.—A deck fixture in the nearest passages, controlled by a switch adjacent to the door.

Log Desk.—The lighting is furnished from a bulkhead fixture placed about one foot above the top of the desk.

Lucky Bag.—A switch-and-receptacle for the use of a portable, located conveniently near to the hatch.

Magazines.—The regular lighting of magazines is by magazine lanterns located in the magazine light boxes, and connected to receptacles which are also located in the light box. The reflectors in the lanterns are arranged with reference to the number of dead-lights in the light boxes. In some cases it is necessary to increase the height of the lanterns by blocking up in the boxes in order that the light may be thrown towards the floor rather than horizontally or up.

The light boxes are of two types: One in which the magazine deck light box is inserted through the deck above, and one in which the magazine light box is inserted in the bulkhead.

Masts.—In military masts fitted with ladders for access to tops and where the lower parts, on the level of the bridges or chart house, are used for the location of wiring appliances, it is necessary to install bulkhead fixtures as may be required, and also switch-and-receptacles for a portable to be used when housing the topmasts.

Mess Tables.—The arrangement of overhead lighting should be made to include at least one deck light nearly over each mess table.

Motor-Control Panels.—The location of lights in the adjoining space should be so arranged that the proper amount of light is furnished for the operation of the panel and for replacing of fuses as required.

Offices (Admiral's Captain's, Executive Officer's, Paymaster's, Navigator's, Ordnance Officer's, Printing).—For standing desks, ceiling fixtures No. 3 are installed; for roll-top desks, the desk light with desk light hooks, suitably located.

Pantries (Admiral's, Captain's Wardroom, Junior Officers', Warrant Officers').—The overhead lighting is from deck light fixtures; a switch-and-receptacle is installed for a N. W. T. portable, for use in cleaning those locations not directly lighted.

Prison.—A deck light inside, with a switch outside of, and adjacent to the location.

Quarters, Warrant Officers'.—Ceiling fixtures No. 3 are used for overhead lighting.

Quarters, Petty Officers'.—Ceiling fixtures No. 3 to be installed for general lighting. Two or more desk lights as required.

Racks, Life Preserver.—The arrangement of lights on the

decks on which the life preservers are stowed should include the necessary amount of light to afford access to them.

Range Finder.—A switch-and-receptacle for a portable, for use in reading the scale, provided none are supplied for guns in the same military top.

Riding Bitts.—The portable for the anchor crane will usually suffice.

Room, Ammunition-Passing.—Deck fixtures overhead similar to ammunition passages.

Room, Band.—Deck fixtures overhead similar to armory.

Rooms, Bath (Admiral's, Captain's, Wardroom, Junior Officers' and Warrant Officers').—Deck lights overhead and a switch-and-receptacle for use in cleaning. When partitions are installed the even lighting of the compartments may be facilitated by placing the fixture over the divisions provided the remaining space above the division will admit of the ready removal of the guard and globe.

Rooms, Blower.—Deck fixtures located with reference to the best general service and a switch-and-receptacle for a portable for local examination.

Rooms, Bread-Mixing.—Deck fixtures overhead, located to shine in the bread troughs.

Rooms, Cleaning Gear.—Deck fixtures located so as to be uninjured by the handling of the gear.

Room, Cold-Storage.—Switch-and-receptacles for portables in the passage leading to the doors.

Room, Communication.—Deck lights overhead and a switch-and-receptacle for a portable.

Room, Draughting.—Ceiling fixtures No. 3 for general lighting and a desk light for each desk or drawing table.

Room, Drying.—Deck and bulkhead fixtures as required.

Room, Dynamo.—The lamps on the head boards of the dynamos, excepting in small rooms, are not considered as contributing materially to the lighting. The direct lighting of switchboard instruments is furnished by brackets attached to their panels, the supply from any separate generating set inside of its circuit breaker being provided in a panel.

For each generating set there should be installed a switch-and-receptacle for a portable to be used in examination or repair. One

of these will also be available for use back of the switchboard in cleaning, adjustment or repair.

The workbench, log desk, gage board, clock, thermometer, oil filters, etc., also require lighting.

The following are occasionally installed in dynamo-rooms and in these cases must be provided for: Action-cut-out switches, battery lockers, battery transfer switches, oil tanks, and lamp lockers.

When not practicable to install brackets at the rear side of the switchboard, bulkhead or drop lights are to be provided from the busbar circuit sufficient for all necessary examinations of the joints, etc., of the busbar and instrument connections.

In addition to these lights the distribution should be on a liberal basis for the cleaning, examination, use and repair of: Steam separator, steam traps, reducing valve, steam valves, exhaust valves, generating sets, switchboard switches, switchboard fuses, circuit breakers, shunt rheostats, ventilating motors if installed, ammunition shunts if installed, searchlight rheostats, annunciators, voice tubes and rotary transformers.

Room, Evaporator.—Bulkhead or drop lights as required for the pressure gages and water columns; deck or bulkhead lights for general lighting in removal of heaters; and switch-and-receptacle for use in examining and cleaning the interior of the evaporator.

Room, Fixed-Ammunition.—When required for constructional reasons, as in destroyers and gunboats the magazine lantern (a fixture secured to a bulkhead) should be used. Otherwise the regular light boxes to contain the magazine lantern.

The locations depend entirely upon and follow after the stowage of the ammunition.

Rooms, Engine.—The lighting of the main engine rooms requires most careful consideration as probably in no other part of the ship are there a greater number of details for which highly efficient lighting must be supplied, in order that the necessary supervision over the lubrication and action of the moving parts of the machinery may be facilitated. As far as practicable fixed lights should be used, and the movable lights generally restricted to accessory purposes and inner bottoms. Movable lights in engine and fire-rooms are the most frequent causes of grounds.

Very satisfactory results have been obtained with from 400 to

600 cubic feet of volume of engine-room compartment, to one 16-candle-power fixed light; each detail, however, requires individual consideration and the usual appliances may be enumerated as follows:

Engine Rooms.

Water service.
Engine turning.
Oil feeds.
Oil tanks.
Starting gear.
Gage board.
Bunker lights.
Condenser, main.
Condenser, auxiliary.
Bunker escape doors.
Air locks.
Platforms.
Indicator cocks.
Voice tubes.
Indicators.
Inner bottoms.
Fire and bilge pumps, main.
Fire and bilge pumps, auxiliary.
Circulating pump, main.
Circulating pump, auxiliary.
Feed pump, main.
Feed pump, auxiliary.
Shaft pump, for bilges.
Air pump, main.
Air pump, auxiliary.
Bunker portables.
Ladders.
Gangways.
Annunciators.
Telegraphs.
Manifolds.

Boiler Rooms.

Gages.
Blowers.
Manifolds.
Bunker Escape Doors.
Annunciators.
Passages.
Ladders.
Columns.
Inner blowers.
Bunker lights.
Bunker portables.
Voice tubes.
Air locks.
Platforms.

Gangways.—Whenever practicable, the conduit to the cylinder and steam-chest light should be from overhead to avoid the effect of the vibration of the engine.

One arc lamp is provided for each fire-room and two arc lamps for each engine room, as may be practicable in the space available.

Room, Handling, Turret.—The lighting to be based on 500 cubic feet of space to each 16-candle-power fixed lamp. The location of the lights to be preferably overhead. Two switch-and-re-

ceptacles to be installed with portables for the examination of the gear.

Room, Ice-Machine.—Deck, drop or bulkhead lights are required for the operation of the lubricating devices, pressure-gauges, working parts of the machine and the ice-working appliances. A switch-and-receptacle for a portable for each machine.

Room, Lamp (oil).—One bulkhead or deck fixture for general lighting.

Room, Oil.—A switch-and-receptacle, located outside, for the use of a water-tight portable.

Room, Operating.—A cargo reflector or 5-light reflector over each operating table to be supplied from a switch-and-receptacle, in the one case, or permanently installed in the other. Also two switch-and-receptacles for portables for each operating table.

Room, Paint-Mixing.—General lighting by deck fixtures. A switch-and-receptacle for portable.

Room, Issuing.—General lighting by deck fixtures. Two switch-and-receptacles, one for a desk light at desk and one for a portable for use in shelves and lockers.

Room, Reception, Admiral's.—The lighting to be on a basis of 500 cubic feet of space to each 16-candle-power in fixed overhead lights. Ceiling fixtures for overhead lighting. Brackets for lights on bulkhead, etc.

Room, Refrigerating.—Same as Cold Storage.

Room, Shell.—Same as Magazines.

Stateroom for Admiral, Captain, Chief of Staff, Personal Staff.—Overhead lighting by ceiling fixtures No. 1 or No. 3. A double receptacle for desk light and bracket fans.

Staterooms for Wardroom Officers, Junior Officers, and Warrant Officers, a double receptacle for desk light and bracket fan, and one commercial ceiling fixture overhead.

For chief petty officers, master-at-arms, and sergeant of marines a switch-and-receptacle for desk light.

In all the foregoing staterooms desk light hooks and cup hooks are installed according to the requirements of the locations in order to afford the greatest facility in the use of the lights at various parts of the rooms, for reading, writing, shaving, etc.

Room, Wirless-Telegraph.—A desk fixture overhead for general lighting and a switch-and-receptacle for desk light for use

in keeping log and examinations of appliances if required. All circuits to be in conduit to prevent reduction from the ærial.

Searchlight Platforms.—A switch-and-receptacle for battle lantern for use in replacing carbons, etc.

Shop, General Work.—The lighting to be on a liberal basis approaching 500 cubic feet of space to each 16-candle-power fixed lamp.

Each machine tool to be provided with a switch-and-receptacle for portable so spaced that all can be operated simultaneously.

Shower Baths (Officers', Petty Officers', Machinists', Crew, Freemen, and Servants).—Deck lights overhead.

Sick Bay.—A standing bulkhead light located with reference to affording only sufficient light for passage purposes at night.

Overhead lighting to be from deck fixtures. Double receptacles for portables for use in examining, taking temperatures of, and administering medicine to patients and also for bracket fans. A switch-and-receptacle for desk lights at desk.

When electric heaters are supplied, outlets for them are provided.

Side Ladders.—See Gangways.

Sighting Hoods.—In each sighting hood of the turret is installed a turret-hood fixture.

Signal Tower.—A switch-and-receptacle for a battle lantern.

Sounding Machine.—A switch-and-receptacle for a deck lantern.

Sounding Rods and Tubes.—No special lighting is required.

Scuttle Butt.—The deck or bulkhead lights in the vicinity will ordinarily suffice.

Scuttle Escape Doors.—See Bunkers.

Scuttle, Ammunition-Passing.—A switch-and-receptacle to be located near by for the use of a battle lantern.

Seamen's Head.—Deck fixtures for general lighting, and a switch-and-receptacle for use of portable in cleaning.

Shaft Alley.—A deck or bulkhead light at each bearing and located for the examination of the action of the lubricating devices. Two switches-and-receptacles in each compartment for use in cleaning and repair.

Steering Compartment.—Deck and bulkhead lights as required on a basis of 500 cubic feet to each 16-candle-power fixed light in the vicinity of the engine and gear; the indicators, dials, and lubri-

cating devices being specially provided for. A switch-and-receptacle for a portable to be located on each side.

Storerooms.—A switch-and-receptacle for a portable to be installed outside of the following storerooms, usually one portable for each two adjacent store rooms:

Admiral.
Bread room.
Chief petty officers'.
Construction.
Equipment.
General.
Battalion outfits and equipments.
Machinery.
Ordnance.
Sails.
Yeoman.
Captain.
Commissary.
Clothing and small stores.
Dry provisions.
Electrical.
Medical.
Junior officers'.
Marines'.
Paints and oils.
Warrant officers'.

Submarine Mines.—Same as Magazines.

Tiller Room.—Deck or bulkhead fixtures as required to examine the action of the lubricating devices; and a switch-and-receptacle for a portable for use when shipping and unshipping the spare tiller.

Admiral's and Captain's Dining-room, Wardroom, Messroom.—Ceiling fixtures No. 1 for overhead lighting on the basis of 400 cubic feet to each 16-candle-power fixed light; in order to give good lighting over the table, two of the overhead lights so determined should be either 3-light or 4-light electroliers or to be one in the center as necessary. Double bracket fixtures, at least two should be installed for side lighting, and a single bracket fixture placed over each side of the sideboard. At least two outlets should be installed for desk lights to be used as reading lights on the tables.

Wardroom Country.—Ceiling fixtures No. 1.

Washrooms (Petty Officers', Machinists', Firemen, and Servants').—Deck fixtures or bulkhead fixtures as required and a switch-and-receptacle for portable for use in cleaning.

Table, Chart.—A switch-and-receptacle for desk light.

Table, Mess.—See Wardroom, Messroom.

Tanks, Fresh-Water.—A switch-and-receptacle for portable,

located conveniently to the man-hole, to be used when inspecting and cleaning.

Tanks, Trimming.—A switch-and-receptacle for portable located conveniently to the man-holes.

Tops, Military, Upper and Lower.—Switch-and-receptacles for battle lanterns for use of guns, range finder, etc.

Torpedo-Rooms.—Deck and bulkhead fixtures as required on a basis of 500 cubic feet to each 16-candle-power fixed light. A switch-and-receptacle for a portable at each under-water torpedo tube.

Trunks, Ammunition.—No outlets.

Trunks, Coaling.—No outlets.

Turrets.—Switches-and-receptacles for battle lantern at rammer, elevator, and training-motor controllers.

The dial of the angle of train indicator to be lighted by a fixed 5-candle-power lamp fitted with a screen. (See also Sighting Hoods.)

Up Takes.—Bulkhead or deck fixtures as required.

Urinals (Officers', Crew, Firemen).—Deck or bulkhead fixtures as required and a switch-and-receptacle for portable in cleaning.

Water Closets (Admiral's, Captain's, Chief of Staff, Officers').—Ceiling fixtures No. 1 and a switch-and-receptacle for cleaning.

Water Closets (Petty Officers' and Machinists').—Deck fixtures and a switch-and-receptacle for cleaning.

Winches, Deck and Coaling.—Bulkhead or deck fixtures or adjacent bulkheads, stanchions or boat-stowage frames; located with reference to good lighting on the drums and controlling devices. A switch-and-receptacle for deck lantern for each winch.

Windlass, Enclosure, and House.—Deck or bulkhead fixtures on each side and as required at the controlling devices. A switch-and-receptacle for portable for general use.

Determination of the Motor Load.

Unlike the lighting load, the motor load is simplified by the absorption of a large proportion of energy and the apparatus is located with reference to convenience and use; and its determination can be readily made as in the table facing page 572.

Determination of Interior Communication and Signal Load.

The division and amount of the energy required for interior

communication is evidently derivable from that required for the various devices which it has been planned to use.

The energy for signal use is computed in the lighting load.

Tabulation of Outlets.

The position of the various outlets for lighting, motor and interior communication use are next entered on the plans, by appropriate symbols, from which an exact tabulation is made on printed forms. From these plans and forms the various outlets are then grouped collectively on the submain, main, and feeder.

Laying Out the Wiring Plan.

The well-developed grouping of the load on submains, mains, and feeders, considering the economics of the case and the many conflicting and intervening continuances of construction of a ship's details requires experience and the draughtsman's art, but is developed along certain specified lines and rules of practice, the essentials of which follow.

Feeders.—Feeders are those lines of wiring which connect directly to the switchboard, and are divided into three general classes: Feeders for lighting circuits, feeders for motor circuits, and searchlight feeders.

Lighting Circuits.—No feeder is to have a greater carrying capacity than 75 amperes, this to be on a basis of 0.5 of an ampere for 16-candle-power incandescent lamps or 1/12-horsepower fans, and 1 ampere for 32-candle-power incandescent lamps or 1/6-horsepower fans.

The feeders are classed in two sub-divisions, *feeders for lighting service* and *feeders for battle service.* The lighting service feeders must evidently be sufficient to carry the entire full-connected lighting load of the ship and all desk and bracket fans, exclusive of that for battle service. The battle service feeders are separate and carry only that lighting load which will be used in action, day or night, and, therefore, the disposition of switches on the switchboard should assure that no unauthorized lighting can be fed by the battle service. The authorized lighting for a battle service is to include every light installed below the protective deck and all lights above the protective deck whose use are necessary while the ship is in action; this includes lights for operation of guns; at ammunition hoists; at boat cranes; at controllers;

in military tops; on searchlight platforms; in the conning tower; in the signal tower; in turrets; one or more of the lights in chart house and pilot house; all signal and running lights; binnacle lights; instrument lamps; at main blowers when they are located above the protective deck; and merely sufficient fixed lights to allow access to such passages and compartments as may be necessary in time of action.

Lighting service feeders are numbered and designated by the terms forward and aft, by decks or specific compartments, and are further divided into starboard and port as may be necessary to properly distinguish them.

An especial division of the lighting and battle service is the *Signal Circuit,* which requires a separate feeder and is installed to be connected to the battle circuit through a 50-ampere D. P. D. T. transfer switch. The circuit feeds outlets for chartboard, truck lights, wigwag, anchor lights, whistle operator, night signal, all telegraphs, pelorus, binnacles, peak lights, top lights, stern light, running light, towing light. (The running lights and towing light are installed on a conveniently located group switch and independent of all other lighting on the circuit.)

Arc lights should be installed on separate feeders; these feeders have a cross-section to give a current density of 1000 cm. per ampere at full-rated load, each arc light taking about 4 amperes.

Searchlight Circuits.—Each searchlight has a separate feeder leading from the searchlight distribution panel of the switchboard unless the searchlight and power panels are combined. The feeder leads through the rheostat, ammeter, and circuit breaker direct to the switch terminals located in the searchlight pedestal.

Motor Circuits.—Motors whose normal full-load working currents are less than 50 amperes may be grouped on the same feeder, but no such feeder is to have a load in excess of 100 amperes. Motors doing similar service in the same part of a ship are to be preferably grouped on the same feeder.

Each motor whose normal full-load working current exceeds 50 amperes is to have a separate feeder.

By using a suitable distribution board exception may be taken to above clauses in the case of turrets. Rammer, elevating, and ammunition hoist motors may then use the same feeder.

The area of the cross-section of the feeders for motors is to be

such that the fall in potential from the dynamo terminals to the motor terminals shall not exceed 5 per cent at rated full load; feeders and mains are at the same time to have a cross-section of not less than 1000 cm. per ampere for continuous service and not less than 500 cm. per ampere for intermittent service.

In general, mains lead from feeders through standard feeder junction boxes, having double-pole fuses of standard pattern. The feeder to enter at the end of the junction box, and not at the side. A switch to be installed in the mains to facilitate fusing.

When several mains lead from the same feeder at any one point an approved distributing panel with double-pole fuses of standard pattern for each main may be used. Standard fuses are to be installed.

Protection to Circuits.—It is mandatory in the case of all feeders that they be led below the protective deck or behind armor to the fullest practicable extent.

Inter-connecting Feeders.—The practice of inter-connecting feeders has been discontinued except in the case of those feeders which supply fire- and engine-room lighting. The method is to make a parallel connection for feeders, both forward and aft, on opposite sides of the ship, in order that should the feeders on one side be shot away the feeders on the other side will supply the lights pending repairs.

The mains are never to be used for inter-connecting feeders.

Mains.—The grouping of the lighting loads on submains or on mains requires especial ingenuity, as the main must show not only a convenient grouping for the location, but must also be entirely separate for the two classes of service, lighting, and battle. A preference is usually expressed for looping mains; that is, to have the ends of the positive leg connected together at the feeder and the ends of the negative leg similarly connected, each leg thus forming a closed circuit through the feeder on itself. The advantage is that the drops are better regulated for outlets fed by the main; the objection is that to ensure the advantage it is necessary to feed the loop at two points necessitating an extra feeder box and switch; the dividing line as to a preference is that when the load on the lighting circuit main exceeds 50 amperes a loop is better.

The distinctive term main rather presupposes a lesser office

than that of a feeder, but the distinction is mainly as to the type of junction box that may be used; a maximum carrying capacity of 75 amperes is as permissible in a single lighting circuit main as in a feeder; it should be noted in this connection that the side circuit carrying parts of the feeder junction box are designated for 60,000 cm. capacity and heating should be expected for currents over 60 amperes.

The connections of smaller motors to feeders are made through mains in accordance with the loads prescribed under feeders for motor circuits. They are rarely looped.

Submains.—These are the connections which conveniently group outlets to connect them to the mains which intervene between the submains and their supplying feeders, and consist of a positive and negative leg leading as directly as possible to and by the locations of the outlets. The general rule is the fewer the better.

When practicable, and to simplify wiring, these submains are avoided by making them of the same cross-section as the main and using a " solid " feeder box (unfused).

Branches.—Branches when for a single light, in conduit wiring, are of 4107 cm. twin conductor, and are run in ½-inch I. P. S. conduit. Circuits from distribution boxes to single outlets must be run with 4107 cm. twin conductor. Molding will not accommodate twin wire.

Determination of Wire Sizes.

From the laying out of the circuits the wiring is tabulated. From plan and elevation the length of wire required for the branches to each submain is measured; this gives the number of feet of 4107 cm. wire required. Next the length of the submain is measured; then the length of the mains; then the length of the feeders. In the tabulation is included the number of amperes for each outlet for the branch, submain, main, and feeder for the total connected load. Continuous feeders, or feeders connected to submains, as for motors, are tabulated the same way.

The allowance of circular mils cross-section wire is based on the following rules:

Lighting conductors are to have 1000 circular mils of area per ampere of current; but when by reason of length of run the cal-

culation by formula demands more than 1000 cm. per ampere the determination by the formula is to obtain.

The general formula for calculation of wire size is:

$$C.M. = \frac{A \times 2D \times 10.87}{d} \text{ in which:}$$

C. M. = Circular mils area.

A = Number of amperes of full-connected load.

$2D$ = The length of run back and forth (positive and negative legs), in feet.

10.87 = Resistance of copper at 95 per cent conductively for a temperature correction of the assumed average temperature plus 4 per cent for twist of wires in the strand (really a correction of D).

d = Drop in volts, between supply end and farthest outlet, calculated from the allowed percentage of the standard voltage.

The formula in its convenient form is $\frac{21.74AD}{d}$

The denominator is based on 3 per cent drop for lighting loads, and for motor input on continuous service (desk and bracket fans, portable pumps and dynamotors); and 5 per cent drop for motor input on intermittent services. The values of d in the two cases are: For 3 per cent, 2.4 volts for 80-volt supply and 3.75 volts for 125-volt; for 5 per cent, 4 volts for 80-volt supply and 6.25 volts for 125-volt.

Based on 1000 circular mils to the ampere, the length of run (from start to outlet) would be for the 3 per cent drop; for 80-volt circuit, 111 feet; 125-volt, 173 feet; for 5 per cent drop the length would be: 80-volt, 185 feet; 125-volt, 290 feet. These are the greatest linear distances to which the specification of 1000 cm. per ampere could be applied; greater distances must be calculated, the option to rest always with the method given of selecting the nearest standard conductor which will give the carrying capacity.

Inter-connecting feeders are to be calculated for a cross-sectional area of 1500 cm. per ampere.

Feeders and mains on motor circuits are to have a cross-sectional area of not less than 1000 cm. per ampere for continuous

service, and not less than 500 cm. per amperes for intermittent service.

The calculation for cross-sectional area of any feeder, main and submain is to be based on its total full-connected load.

The calculations are ordinarily provided for beforehand by the construction of a wiring chart, constructed for the two variables of length of circuit and ampereage; from this chart the wire size can be conveniently picked off.

Fuses.

Every reduction in the size of a feeder or main is fused. Fuses for feeders and mains are to be at the rate of 1 ampere per 1000 cm., and to blow at the rate of 1 ampere per 500 cm.

Whenever mains are led off from feeders it is done through standard feeder junction boxes, having double-pole fuses of standard pattern, and to blow on the basis of 1 ampere per 500 cm. of the main.

All outlets are fed from mains by branch wires properly fused.

Fuses for junction boxes are to be for the normal rating of 3 amperes and to blow at 6 amperes for 125 volts, and for the normal rating of 4 amperes and to blow at 8 amperes for 80 volts.

Switches.

The feeders are controlled by switches and fuses or circuit breakers on the switchboard.

Switches are provided on all mains close to a feeder box, to facilitate re-fusing; in the case of looped mains they are placed near both junctions with the feeder.

In every case of a fixed outlet a switch is installed in a location of convenient access.

Contract Specifications.

The plans for the electric installations on contract ships are laid out at the Navy Department.

The "General Contract Specifications," that is, those which are printed in book form and including also the specifications for the vessel and the ordnance outfit, are necessarily incomplete (being prepared before many of the details of the ship are finally settled) but give the general scope of the installation.

As soon afterward as may be practicable more detailed plans are worked up and the locations of the various appliances for generation, control, lighting, signalling, power and interior communication are more accurately determined; from these a detailed specification is issued.

A General Guide to Installation Work.

The standard practice in installing the various details of the electric plant, excepting as to such details of the lighting, etc., as have already been referred to, is comprised in the following:

Dynamo-Room.—In all cases where practicable a separate compartment for the sole use of the generating sets and accessories is provided. It is to be located underneath the protective decks in all ships so fitted. In all other cases it is located with reference to the best attainable protection offered by coal and the water-line.

The dimensions of the room should be such as will allow a working space for the generating sets and accessories installed, not less than as follows:

(a) Between the edges of the foundations for one generating set, on the operating side, and the clear adjacent bulkhead or generating set foundation, a minimum distance of three feet.

(b) Between the edge of the foundation for one generating set, on the rear side, and the clear adjacent bulkhead or generating set foundation, a minimum distance of two feet.

(c) Between the flywheel, or edge of foundation of generating set, if the flywheel projects beyond it, and the clear adjacent bulkhead the distance not to be less than one foot in excess of the distance required by the change in position of the flywheel and that required by the flywheel disconnecting device.

(d) Between the edge of the foundation, on the armature end, and the clear adjacent bulkhead, a distance of not less than six inches in excess of the length of the armature shaft of the largest set installed in line.

(e) The intent of these separating distances is to provide a clear passage around each generating set, sufficient for all necessary operation and repair.

(f) Between the foundation of any generating set installed, and the face of the switchboard, a minimum distance of four feet.

(g) Between the back of the switchboard and the clear adjacent bulkhead a minimum distance of three feet.

(h) A clear access around each end of the switchboard to be of a minimum width of two feet.

(i) The workbench, oil tanks, and spare armature (if stowed in dynamo-room) to be not less than 3 feet from the foundation of the nearest generating set.

(j) Between the top of the cylinder and the clear lower edge of any beam over the piston or valve spaces to be not less than three inches more than the extra room required to remove the pistons or valves.

Generating Sets.—The shaft lines are, when practicable, to be fore and aft, in order to reduce the thrust on bearings when the vessel is rolling.

The sets are located, with reference to their cylinders, so that the deck beams shall not interfere with the removal of pistons and valves.

Each set where furnished in lots of two or more for the same ship is fitted with a metal name plate with figures one inch to two inches high attached to a prominent place, visible when standing facing the commutator, for designating the serial set numbers 1, 2, 3, 4, etc.

The numbering of the sets begins with the forward, starboard, upper set, and continues across the ship consecutively; and then below or aft, according to the location of the dynamo-room.

The bed-plate of the generating set is fitted with brackets for a starting bar.

Stout brass oil guards, capable of ready removal, are fitted, if necessary, to prevent oil being thrown from engine. Brass hand rails are to be provided, attached to and extending around, each generating set, and mounted on the edge of the foundation.

Foundations.—The deck under all generating sets should be primarily so supported and strengthened that it will easily sustain the weight, and ensure that the framing of the vessel will assist in securing rigidity and preventing vibration of the set.

All bed pans are levelled fore and aft and athwartships and consist preferably of a metal pan, with edges turned up about two inches to catch waste oil and water; the pan to rest on and be secured to a wooden layer not less than two inches in thickness,

to deaden vibration. The wooden layer is in turn supported by a metal plate, or channel or *Z* bars secured to the deck.

The usual foundation is shown in cross-section in Fig. 286.

[NOTE 33.—The foundation just described is found insufficient for the purpose for generating sets of larger size than 32 k. w., especially with raised cylinders, the reason being that the usual ⅜-inch deck (even with strong framing) and the wood filling does not prevent deleterious vibration.

The latest plan for the large sets is to overlay the ⅜-inch deck with a solid plate, one inch in thickness (40 pound plate) and bring the bed-plate of the generating set down flush to this heavy plate. As the generator frame extends below the base of the bed-plate, provision is made by cutting out and fitting in a light pan with a drip cock for draining. The wood is omitted when adopting this plan of foundation.]

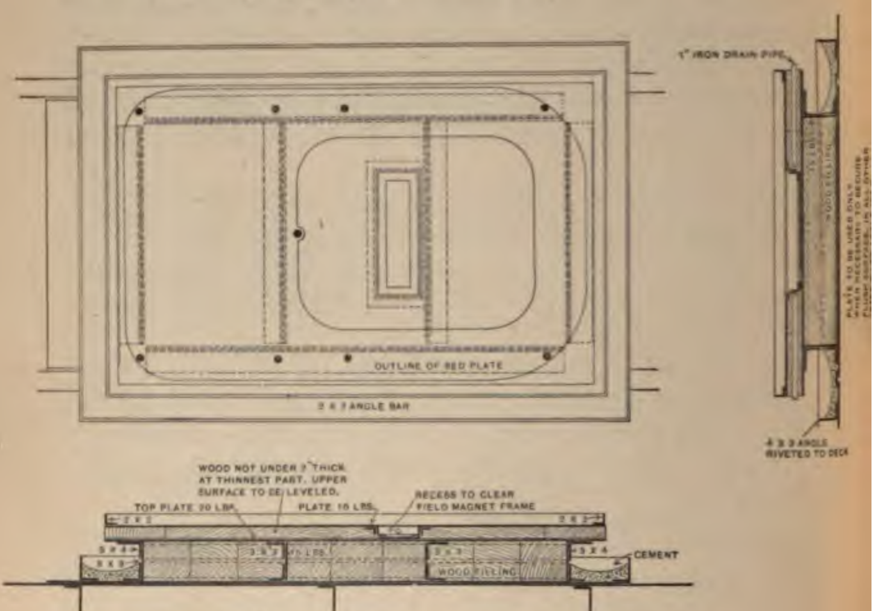


FIG. 286.—Cross-section and plan of usual foundation.

Main Steam Pipe.—This is fitted with a stop-valve, reducing valve, and separator all located in the dynamo-room unless otherwise specified. In no case should it be connected with any engines but those of the generating sets. It is tapped for connections with the steam gauge at each side of the reducing valve.

The dynamo engines are usually provided with steam supply pipes from the port and starboard steam lines or auxiliary boilers,

these pipes being cross-connected in the fire-room. Stop-valves are placed in each supply pipe between connection and the boilers in order that steam may be taken from the port boilers, while the starboard boiler valves are being overhauled and *vice versa.*

Separate Condenser.—The latest and best practice in larger vessels is to install a separate condenser in the dynamo-room, or in an adjacent compartment for the sole use of the dynamo engines.

Main Exhaust Pipe.—This is fitted with a stop-valve, placed where it will be accessible in the best position to insure minimum condensation in the branch exhausts, the exhaust pipes being led directly to the condenser. In no case should these be connected to a common auxiliary exhaust nor with the low pressure receiver of the main engines. The pipe is to be tapped for a combined vacuum and back pressure gauge. When a separate condenser is installed there should also be connections to the main and auxiliary condensers as well; this is sometimes overlooked.

Branch Steam and Exhaust Pipes.—The steam pipes are fitted with a stop-valve near the main pipes and the throttle at the engine.

Exhaust pipes are fitted with a stop-valve near the main pipe.

Joints.—No joint of steam, exhaust, water pipes, or fire mains should be placed over or in line with the dynamo, switchboard, rheostats, or other electrical apparatus which is liable to injury from leakage.

Leads of Piping.—All piping should be led with especial reference to head room and the facility for removal and repair of pistons and valves, and the attachment and use of the indicators.

Covering of Piping.—All pipes are covered with an approved non-conducting material and protected with canvas or metal.

Steam and Vacuum Gauges.—The two gauges on the steam pipe and the one on the exhaust pipe are mounted together on a back board, with an indication by marking on the dial or name plate as to their connection.

Separator.—A separator for at least each two dynamo engines installed should be provided; each to be of a capacity of eight times the volume of the high-pressure cylinder.

Reducer.—A reducer is installed if the rated pressure of the generating set is below that of the usual boiler pressure as shown by the dynamo-room gauge.

Traps.—These are to be of large capacity and so connected as to take the condensation of the separator. The drip pipes of the engines and drains from the lower ends of all piping to connect to the discharge side of the trap.

Dynamo-Room Fittings.—*Oil Tank.*—This should be located below the protective deck and in the dynamo-room if at all practicable. *The location should be well up to the overhead deck in order to provide a gravity supply, with facilities for draining and for filling from deck above; and be fitted with necessary piping and cocks for drawing off at each generator set. If a gravity supply is not practicable, a hand- or motor-driven pump should be provided for forcing the oil to each generating set.*

The oil tanks are provided with a name plate giving the capacity in gallons and also with an oil gage graduated to show the contents in gallons and a cock for cutting off that tank from the supply.

The tank capacity for a ship is based on the following for each generating set:

K. W. Capacity.	Allowance of Oil. Gals.
16	20
24	25
32	30
50	40
75	50
100	60

Oil Filters.—If space will admit, two filters are supplied for the dynamo-room.

K. W. Capacity of Sets in Room.	No.	FILTER. Capacity of each Filter. Gallons.
5	2	10
8	2	10
16	2	30
24	2	30
32	2	30
50	2	60
75	2	60
100	2	60

If the construction of the filter includes heating coils they are connected with the steam and drip main.

An oil set and oil set bracket is to be installed in each division of the dynamo room.

Save Alls.—These are for catching the waste oil from the drain pipe of the engine base. The following table gives standard sizes:

K. W. Capacity of Set.	Size. Length. in.	Width. in.	Depth. in.
5 & 8	8	4	4
16	10	5	5
24	10	5	5
32	10	5	5
50	12	6	6
75	12	6	6
100	12	6	6

Waste Tank.—Two waste tanks are provided in each dynamo-room, one for the oily waste and the other for the clean waste; to be marked respectively *Dirty Waste* and *Clean Waste.*

They are of the following sizes:

Oily waste tank, 11¼ inches diameter, 15 inches high.

Clean waste tank, 20 inches by 15 inches by 20 inches high.

Workbench with Vise.—This is installed in the dynamo-room when practicable, and to have drawers beneath for stowage of tools.

Test Panel.—If practicable, this is installed near the work-bench, for testing fuses, portables, lamps, etc.

Wrench and Tool Board.—These are conveniently placed near the workbench, and arranged for securing the tools in place.

Lifting and Transporting Devices.—These are not required for sets of and below 5 k. w. For heavier sets they may consist of two differential pulleys and a traveller. If no traveller is provided, eye bolts with links are fitted overhead as required for lifting any heavy part, and for transporting it to the hatch or door of the dynamo-room. The lifting capacity of the pulleys should be ample for handling the heaviest part that may be required to be moved in the dynamo-room.

Spare Armature Supports.—One set of supports installed for each size of generating set, in each dynamo-room. Duplicate sets are not required to be installed for adjacent dynamo-rooms.

Canvas Covers.—The spare armature is to be provided with a close-fitting, laced, khaki cover.

Log Desk.—This is located with reference to the switchboard and gages, if practicable, and is provided with a drawer large

enough to take rough sheets (11 inches by 18 inches) of the electrical journal.

A block fitted for the clock and psychrometer is secured over the log desk.

Lockers.—One of each dynamo-room is provided for stowage of such tools as are not placed on the tool board; and for the indicator, portable ammeter, portable voltmeter, testing generator, and tachometer.

Dynamo Leads.—The dynamo and equalizer leads have a cross-section on the basis of 1500 cm. per ampere of the rated capacity of the dynamo, and lead to the switchboard on porcelain insulators. Areas required in excess of standard size are obtained by paralleling smaller cables.

When three or more dynamos are to be connected to the same switchboard, the resistance of the equalizer leads must not vary more than 5 per cent from one another. To obtain this degree of equality of resistance where, owing to the relative locations of dynamos and switchboards there is an inequality of distance, the lead of the shorter one is lengthened by looping.

The arrangement of dynamo leads must be such as to ensure the equality of division of load in parallel operation in conformity with the requirement of 20 per cent in the specifications for generating sets. (See Paralleling, page 490.)

Storerooms.—These are located near the dynamo-room and fitted with desk and workbench in case it has not been possible to locate the workbench in the dynamo-room.

Shelving and lockers are provided for the storage of spare parts of all motors installed, spare parts of generating sets, tools not ordinarily in use, parts of lighting fixtures, searchlight carbons, spare lamps, spare wire, fuses, battery supplies, the illuminating outfit and its spare parts and lamps, and portables not in use. A metal waste tank is installed having capacity to take the ship's allowance of waste, and so constructed that one side is removable in order that a whole bale of waste can be put in at a time.

Switchboard and Rheostats.—The location should be as high above the deck as convenience of access to the appliances and available space will permit; and to be placed clear of the dripping from valves, dead-lights, joints of steam, exhaust and water pipes, and fire mains, or condensation from ventilating or water pipes overhead.

The top edge of the switchboard should be not more than seven feet above the deck. It is to be installed with special reference to accessibility and protection against oil thrown by the moving parts of the generators and engines. A hand rail should be fitted across the front of the board.

Switchboard.—The switchboard leads coming up from below have the deck stuffing tubes or conduit to extend at least six inches above the deck, and rise up within six inches of the center line of the board.

The metal framing supporting the switchboard is to be rigidly secured to the deck at its lower part, and the upper part secured to the bulkhead or deck overhead in a manner that will allow a vertical displacement, in the event of the deck being injured, with a minimum of horizontal displacement.

Switchboards should also be fitted with suitable brackets for the switch levers and voltmeter plugs when not in use.

Shunt Rheostats.—These are so installed as to interfere the least possible with the accessibility to the bus connections; preferably at the top of the board, using, if required for this purpose, sprocket and chain connection.

Searchlight Rheostats.—The searchlight rheostats are located as conveniently near to the panel as space will admit, and are marked with the names corresponding to their respective lights. The resistance part may be separated from the control to facilitate installation and keep heat from instruments.

Running Lights, Signal Lanterns, Truck Lights, Night-Signal Set, Searchlights.—*Running lights, towing range, and top lights* are furnished with, and connected to, two lengths of double conductor, plain, and two receptacle plugs; the lengths of conductor being that best adapted for connection with the receptacles. Receptacles for the foregoing lights are placed conveniently near the lights and without switches. The junction boxes are to be easily accessible for replacing and inspecting fuses.

Signal lanterns are furnished with, and connected to, a length of double conductor, plain, and a receptacle plug; the length of conductor being that which is required for the especial use. The peak light cable and ladder are in accordance with standard drawing. Ordinarily four red, eight white, and three green signal lanterns are provided for each vessel.

Double-truck Lights.

Double-truck lights are installed on the fore and mainmasts of vessels having two or more masts. Single-masted vessels have a double-truck light on at that mast. Torpedo-boats and vessels of special design are not fitted with double-truck lights unless specially authorized. Double-truck lights are furnished with, and connected to, two lengths of double conductor, plain, and two receptacle plugs, the length of conductor being that best adapted for connection to the receptacles; the receptacles are without switches, and are located, in case of use with topmasts, on the bibbs or athwartship brackets of the military top; in the case of pole masts the receptacles are located under the upper deck in which the mast partners. Circuits from the controller to the receptacles are the standard No. 14 B. & S. G. conductor; in case of very long runs 9000 cm. is run if better adapted for the particular vessel.

Night-Signal Sets.

The signalling sets are connected to a 25-ampere switch-and-receptacle, installed on the signal circuit. The lower end of the lamp ladder of the night-signal set is steadied by a galvanized wire cable setting up with a turnbuckle and plate inboard.

The keyboard is located on the bridge where the operator can plainly see the lamps of the signal set, being well secured on the bridge rail or on a suitable pedestal, so that vbrations will not interfere with sending a message. A metal cover is fitted to protect the keyboard from the weather.

For convenience in estimating the conductor size and fuse capacity of the current supply, a standard tabulation is made for the running lights and signals, the navigational instruments and devices including mechanical telegraph lighting and for the night-signal set.

Interior-Communication Circuits.

These circuits are classified as follows:

Call bell circuits.	Warning signal circuits.
Telephone circuits.	Battery control circuits.
Fire alarm circuits.	Turret hoist indicator circuits.
Magazine alarm circuits.	Electric log indicator circuits.

General alarm circuits.
Water-tight door indicator circuits.
Helm angle indicator circuits.
Steering telegraph circuits.
Engine telegraph circuits.

Call Bell Circuits.—Call bell circuits comprise *the quarters and office calls* and *the voice tube calls.* Whenever it is necessary to prevent confusion in calls to the same general location or compartment an annunciator is installed, the number of drops being that convenient for the particular locality.

The actuating switch on call bell circuits is invariably the push button, which is of the non-water-tight type in quarters. In staterooms the push button should be located near the head of the berth. Push buttons at tables are of the pear push type, the cords leading from ceiling buttons; hooks are conveniently placed for hanging the bights of the cords. Push buttons for voice tubes are located, if practicable, directly over or under the mouthpiece.

Quarters and Office Calls.—The standard list of battleship calls comprise the following:

An annunciator with buzzer in the admiral's pantry, with push buttons at the following locations (14 drops):

Admiral's cabin at desk.
Admiral's cabin at transom.
Admiral's cabin over table (one double pear push).
Admiral's after cabin at transom.
Admiral's after cabin over table (one double pear push).
Admiral's reception room at transom.
Admiral's reception room over table (one double pear push).
Admiral's office.
Admiral's stateroom.
Admiral's bathroom.
Forward cabin.
Chief of staff's stateroom.
Chief of staff's bathroom.

Admiral's orderly annunciator with bell located on gun deck bulkhead, with drops for all the preceding calls, except admiral's bathroom and chief of staff's bathroom; also a drop for a call from the signal tower; altogether 12 drops.

Annunciator (8-drop) with buzzer in captain's pantry, with push buttons at the following locations:

Captain's cabin at desk.
Captain's cabin at transom.
Captain's cabin over table (one double pear push).
Captain's stateroom.
Captain's office.
Captain's bathroom.
Forward cabin.

Captain's orderly annunciator (8-drop) with buzzer at the gun deck bulkhead, with drop for the preceding calls, except from bathroom; also a drop call from quarterdeck.

Annunciator with buzzer in wardroom pantry with push buttons at the following locations (the number of drops will necessarily depend upon the number of staterooms):

Each wardroom stateroom.
Executive officer's office.
Navigator's office.
Ordnance officer's office.
Log room.
Paymaster's office.
Wardroom messroom over table (single pear push).
Wardroom messroom over table (double pear push).
Wardroom messroom starboard at transom.
Wardroom messroom at transom (port).
Wardroom country, at transom.
Wardroom bathroom (all push buttons on the same drop).

Annunciator with buzzer in junior officer's pantry with push buttons in the following locations (number of drops dependent upon the number of staterooms):

Each junior officer's stateroom.
Junior officer's messroom (all push buttons on same drop).
Junior officer's bathrooms (all push buttons on same drop).

Annunciator with buzzer in warrant officers' pantry with push buttons in the following locations (number of drops dependent on the number of staterooms):

Each warrant officer's stateroom.
Warrant officers' messroom (all push buttons on same drop).
Warrant officers' bathrooms (all push buttons on same drop).

Buzzer in yeoman's storeroom with push button in executive officer's office.

Annunciator with bell on quarter deck for messenger, with push buttons in executive officer's office, executive officer's stateroom, and to the double pear push over wardroom mess table.

Buzzer for navigator's writer with push button in navigator's stateroom.

Buzzer in paymaster's office with push button in paymaster's stateroom.

Buzzer in paymaster's issuing room with push button in paymaster's office.

Buzzer at first sergeant's desk with push buttons in marine officer's stateroom.

Bell for printer with push button in admiral's office.

Buzzer in electrical gunner's stateroom with button in navigator's stateroom.

A few other calls are installed as may be considered necessary from differences in ship construction.

Not more than one drop on any one annunciator are assigned to the same room or compartment for a similar purpose, but this one drop may be operated by several push buttons located in various places in the same room or compartment.

Boat Hour Gongs.—Push buttons on quarter deck operating the single stroke 5-inch gongs which are located as follows:

Gun deck.	Berth deck on barbette forward.
Berth deck on after bulkhead.	Berth deck on barbette aft.

Voice Tube Calls.—Voice tubes should not be installed when the length of tube will exceed 250 feet, and, as a rule, the length of any angle tube should be limited to a length of 200 feet.

Voice tubes to be 2 inches in diameter except in the cases below mentioned. For short, direct leads 1½-inch tubes are allowed as for ammunition hoists and ash hoists; for long lengths the 3-inch size is installed when and where directed. Attention is called in every case by bell. When there are two or more outlets an annunciator is installed. Return calls are installed at each end of continuous voice tubes, call to be made by bell, and not by whistle alone. Valves for branches are installed as directed.

The usual voice tubes installed in a battleship and which are of 2-inch size are:

Pilot house and conning tower to:

Steering engine room.	Signal tower.
Both engine rooms.	Observation platform.

Conning tower to:

Forward turret.	Upper foretop.
After turret.	

Communication room to main deck, usually two tubes; a tube to each gun position on the gun deck, with two extra for the gun division; also a tube to both lower tops.

Starboard (or forward) distribution room board to:

Main deck.	Passage, upper platform.
Upper deck.	Port (or after) distribution board.
Forward handling room.	Starboard (or forward) dynamo-room.
After handling room.	Port (or after) dynamo-room.
Forward projectors.	
Foretop projector.	

Port (or after) distribution room board to:

The same stations as for the starboard (or forward) board, except to lead to the named locations for the after part of the ship and for the after searchlights.

Port engine room to each port fire-room.

Fire-rooms to each other, as follows:

Fire-room No. 1 to fire-room No. 2.
Fire-room No. 1 to fire-room No. 3.
Fire-room No. 2 to fire-room No. 4.
Fire-room No. 3 to fire-room No. 4.
Fire-room No. 3 to fire-room No. 5.
Fire-room No. 4 to fire-room No. 6.
Fire-room No. 5 to fire-room No. 6.
Fire-room No. 5 to fire-room No. 7.
Fire-room No. 6 to fire-room No. 8.
Fire-room No. 7 to fire-room No. 8.

From each ash hoist on the main deck to the location of ash heaps in the fire-room.

For each ammunition hoist from:

Point of delivery to loading location below.
Loading location to motor.

Gun deck, starboard and port, two tubes from selected locations

through the bulkhead; also two tubes from selected locations to the 6-inch guns on both sides of the main deck.

A voice tube is installed between the pilot house and the standard compass.

The following are generally installed in 3-inch tubes, with flaring mouth-piece: Pilot house to chart house; pilot house and conning tower to communication room and signal tower to communication room.

Notes on Voice Tubes.—Such of the voice pipes terminating in the communication room as may be considered necessary are continued up to the conning tower.

The voice pipes leading from the pilot house and conning tower to the starboard engine room, port engine room, signal tower and observation platform; and from the conning tower to the forward turret and after turret, are continuous through the conning tower to the pilot house and are fitted with 3-way valves. They have separate calls to each station.

All voice pipe mouths have an approved pattern, and, excepting in the conning tower and pilot house, leads to the engine rooms, whistles are installed. Voice pipe outlets are bell mouthed and fitted with hinged metal covers. The whistle is on the side of the bell and not on the hinged cover. Electrical calling apparatus with return calls is installed for each voice pipe outlet, excepting ammunition hoist and ash hoist tubes; the same annunciator bells and the like used in connection with the telephone calling system may be employed when available. Buzzers are used in all locations not subject to noise which might render the signal inaudible. Locations having but one voice pipe and one telephone call may be fitted with both a bell and a buzzer in lieu of an annunciator. Other locations having more than one call are fitted with a suitable annunciator operated in connection with a bell or buzzer, as the case may require.

Voice pipes in addition to the above list are installed as may be deemed necessary to render the system efficient and complete.

The efficiency of a long lead of voice tube being materially affcted by elbows and bends, it is essential that all leads be as direct as possible and free from any unnecessary bends and offsets. All necessary bends, offsets, and elbows are made by bending a piece of the voice pipe to the required shape, excluding to the greatest possible extent the use of separate elbows and the like.

Telephone Circuits.

[NOTE 34.—It is not practicable to derive from present installation practice any fixed rule for telephone circuits as the practice is one of continual change and will be much influenced by the determination of an efficient and acceptable system of fire control. It is a matter of grave doubt whether telephone communication can be relied upon in action, owing to the effect of gun shock upon the material of the microphone, whose particles invariably pack under that action. Up to the present the lines are led to a switchboard located in the communication room, the type of board being that derived from the ordinary board of commercial practice, and supplied by the Western Electric Company.]

Fire Alarm Circuits.

The annunciators are located in the dynamo-room unless otherwise directed. The thermostats are placed in metal cases over-

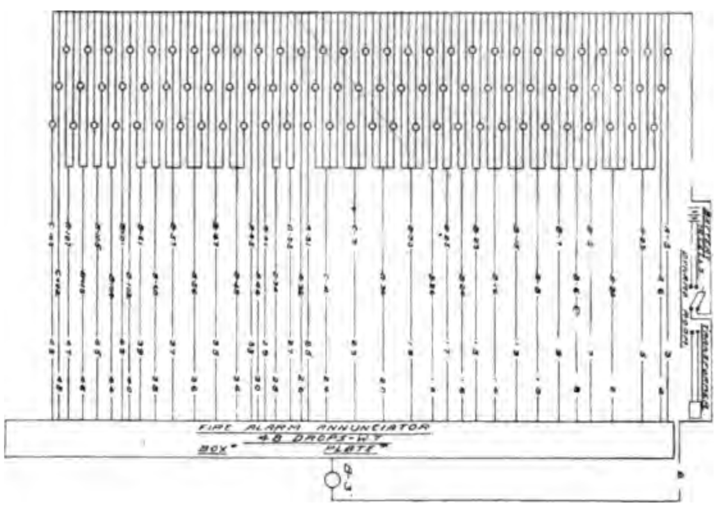


FIG. 287.—Fire alarm circuit diagram.

head in the storerooms and on bulkheads in all bunkers about three feet from the bottom of the bunkers, and in that part of the bunker which is most exposed to heat from the boilers.

All thermostats in any one compartment are connected in parallel, and coal bunker thermostats, magazine thermostats, and storeroom thermostats are indicated on separate annunciators.

Thermostats are installed in the following storerooms:

Construction.
General.
Machinery.
Commissary.
Equipment.
Electrical.
Clothing and small stores.
Ordnance.
Infantry stores and equipments.

Admiral's.
Captain's.
Wardroom.
Junior officers'.
Warrant officers'.
Marine's.
Chief petty officers'.
Paymaster's.
Miscellaneous storeroom.

A typical set of connections for one annunciator is shown in Fig. 287.

Magazine Alarm Circuits.

The circuits are distinct and separate from the fire alarms. The

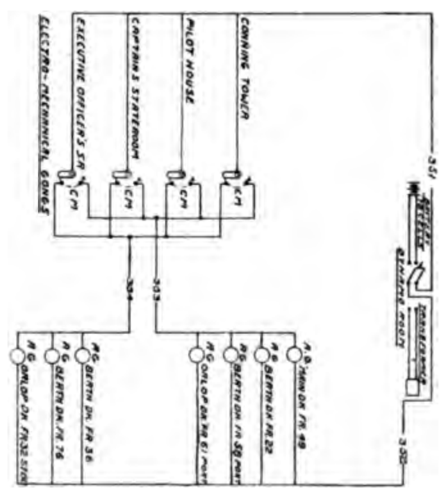


FIG. 288.—Diagram of general alarm circuit.

annunciator is installed in the dynamo-room. The thermostats are installed in magazines, shell rooms, torpedo-head rooms, submarine mine rooms, and as per plans.

The connections are similar to those for the general fire alarm circuits as shown in Fig. 287.

General Alarm Circuits.

The gongs are so located in the living and working spaces as to be heard by all the ship's force. The gongs are operated by push

buttons located in the chart house, conning tower, and the staterooms for the captain and the executive officer. All push buttons for the general alarms in these locations are covered by a metal cover which will require removal prior to operation and thus prevent mistake. A typical set of connections is shown in Fig. 288.

Water-tight Door Indicator Circuit.

The indicators are installed in the chart house or on the bridge, their connection plan being a part of the specified arrangement of circuits for the water-tight door installation.

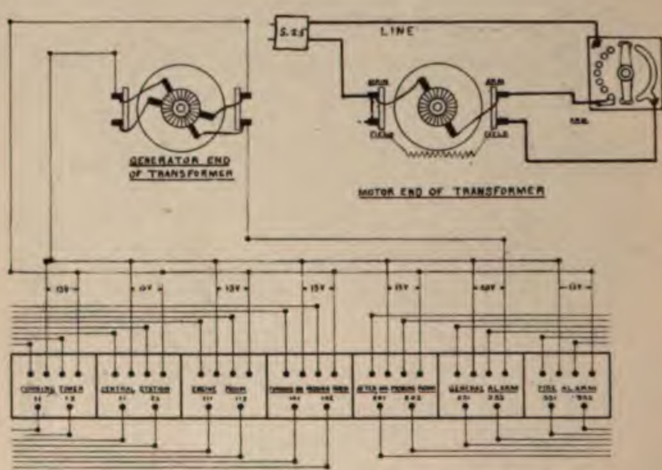


FIG. 289.—Diagram of warning signal circuit.

Warning Signal Circuit.

The shrill whistles are installed in sufficient number and so located as to be heard in all compartments below the protective deck, and in all other compartments in which the siren is not audible. The operating mechanism is installed on the bridge, in the pilot house, and such other places as may be directed.

A typical set of connections is shown in Fig. 289.

Fire Control Circuit.

As previously stated, the fire control system is still under experiment, and present installations under this head are not now standard.

Turret Hoist and Ready and Ammunition Car Position Indicator Circuit.

The combined signal and position indicators are shown in Fig. 290.

Hoist and Ready Signal.—When the car is ready for hoisting, the plunger switch *P* is pushed, lighting the lamp in the indicator at the hoisting station. As the car starts up, the spring *N* trips the catch *L*, releasing the plunger and extinguishing the lamp.

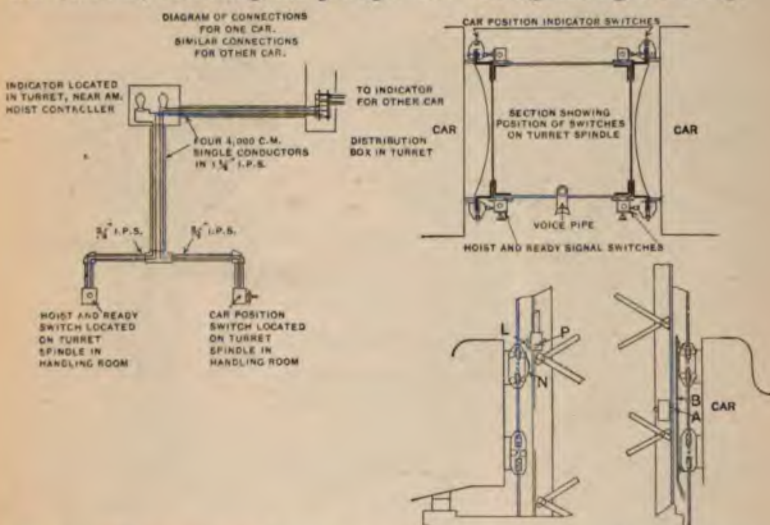


FIG. 290.—Hoist and ready signal and ammunition car position indicator.

Ammunition Car Position Indicator.—A phosphor bronze stop *B* is secured to the ammunition car; and the switch is secured to the track at such a height that, when the car is descending, and is 42 inches from the bottom, the strap will throw the lever of the switch *A*, thus closing that switch and holding it closed until the car reaches within 6 inches of the bottom of its travel; *on the upward journey the switch does not operate.*

In former installations the hoist and ready signal and the ammunition car position indication are separate.

Electric Log Indicator Circuit.

The bracket is located on a davit or stanchion on the quarter deck at each side with outlets convenient of access for the attachment of the transmitter.

The indicator is located in the chart house, and as a rule, but one is furnished.

The typical connections are shown in Fig. 284.

Helm Angle Indicator Circuit.

The contact arc is located in the tiller room. The indicators are located in the steering engine room, conning tower, chart house, on the bridge, and at the wheels aft. Standard action-out-

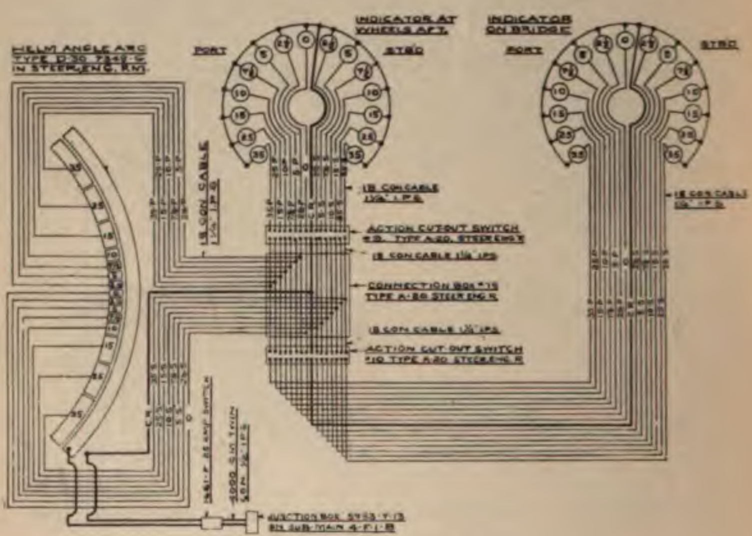


FIG. 291.—Diagram of helm angle indicator circuit.

out switches are placed on the circuits leading to the chart house, bridge, and wheels aft. A typical circuit connection is shown in Fig. 291.

Steering Telegraph Circuit.

The transmitters are located on the bridge, in the chart house, and in the conning tower. The receivers are located in the tiller room, steering engine room, and at the wheels aft. Standard action-out-out switches are placed on the circuits leading to the bridge, chart house, and the wheels aft.

The typical connections are shown in Fig. 292.

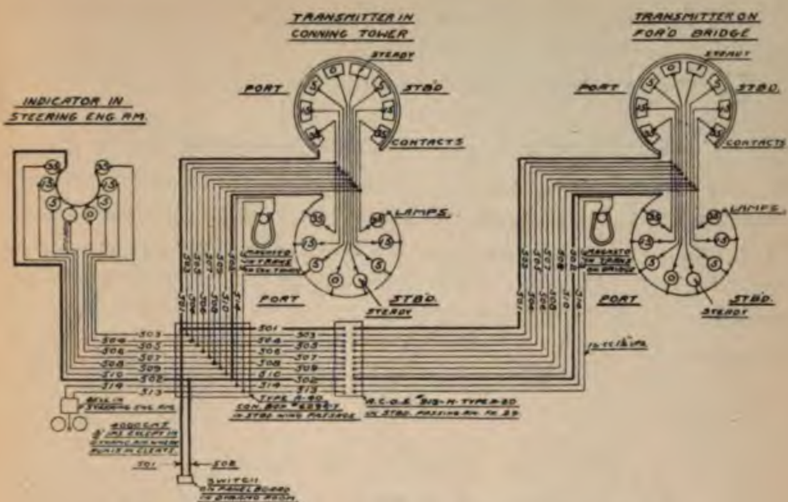


FIG. 292.—Diagram of circuit for steering telegraph.

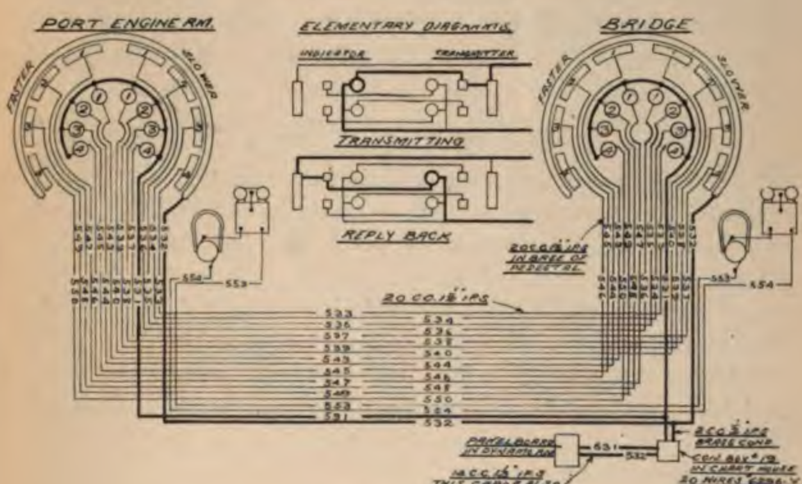


FIG. 293.—Diagram of engine telegraph circuit.

Engine Room Telegraph Circuit.

A combined transmitter and receiver are installed on both bridges (in chart house and conning tower if directed), with a combined receiver and transmitter in each engine room. If not

included in the transmitter, an audible signal is installed to call attention to the sending of an order.

The connections are shown in the diagram of Fig. 293.

Engine Revolution and Direction Indicator.

The transmitters are in the shaft passages; in vessels not provided with shaft passages (or alleys) they are located as far aft as possible. The receivers are located in the engine rooms, conning tower, and on both bridges. Standard action-out-out switches are placed on the circuits leading to the chart house and bridge.

The connections of the Cory type of instrument are shown in Fig. 265.

Panel for Telegraphs and Indicators.

There is installed in the dynamo-room a panel, with double fuses of standard pattern, for the supply of the current to the circuits for wireless telegraph, the rotary transformer for call bells, fire control, electric log indicator, helm angle indicator, steering telegraph, engine telegraph, and engine revolution indicator.

Notes on the Installation of Ducts, Conduit.

The primary and important consideration in the installing of conduit is that each separate line of conduit must be easily accessible for individual removal and repair. This injunction provides a large saving in cost and time for navy yard repairs, and is a vital matter for repairs and for replacing circuits during action; and, as running conduit through beams practicably defeats the intent, *any system of running conduit through beams should be prohibited.* It must be presumed that the beam has been designed to be as light, within the safety factor limits, as proper structural strength will admit and the slightly better appearance is not an excuse for vitiating strength. Again the conduit must be cut for the purpose, entailing extra time, cost, and the extra weight of unnecessary couplings. Drilling for hangers is objectionable even though far less pernicious, and clamping to the edge of the beam is the best practice as it is not only secure, but facilitates installing and removal. In quarters, however, it is often advantageous to run through beams, and the objection for the small piping does

not obtain. Here, as in superstructures, main and gun decks, advantage can be taken of running through lightening holes in the beam knees, being careful that each individual lead is accessible.

No cutting of stiffeners on bulkheads should be permitted except when it is absolutely necessary and only in special emergency. Ordinarily this can be avoided by blocking out the appliances from the bulkheads and connect through a hole through the bulkhead, inserting a nipple.

To facilitate access to the gland in the stuffing tubes a distance of about 4½ inches should be allowed above the top of the gland before the insertion of any union, coupling, or other appliance, in order that the gland may be lifted up.

Dixon's graphite grease is used to complete joints and must be put on all threads before securing into couplings, boxes, etc. Rubbing it on the outside of the joint is not sufficient as an alternative and is valueless as an additional operation. *Clean off any excess that may get to the interior of the conduit.*

A red lead cement is used under washers for joints at decks and bulkheads; it consists of 45 parts of white lead mixed in oil, and 15 parts of dry red lead.

For attaching to the deck beams and stiffeners, hangers are commonly employed which require drilling in the beam only; one is located at each beam, etc., unless the ordinary use of the location is such that there is no likelihood of any strain being put on the conduit, when one at each alternate beam is sufficient; if the hangers are of the sheet metal type they should not be closer together than a length of conduit unless made in small sections.

When the available space is restricted, the conduits may be more closely assembled by securing the hangers alternately to either side of the beam; these hangers are provided for use on angles, on double bulb beams and on single bulb beams, but care is to be taken with sheet metal hangers as in the preceding sentence.

Straps are used for fastening to bulkhead and other smooth surfaces. The metal used is iron for ordinary locations, and brass in locations where brass conduit is employed around binnacles or on wooden masts. The dimensions of the standard straps are such that the conduit is secured closely to the surface to which it is attached. A clearance being required for couplings, unions, etc., special straps are made as required.

In locations where the conduit is not likely to be subjected to any particular strain, such as in quarters, chart houses, etc., a lighter form of strap in both iron and brass is used. The ordinary spacing of straps is about 5 feet.

When fittings are, in themselves, bolted to the decks or bulkheads, this is considered as being equivalent to a strap and none is required immediately beyond the appliance.

When special straps are required under bolts of cylinder heads, steam chests, etc., special width iron is used as required by the diameters of the bolts.

Those conduit fittings which are not provided with methods of fastening are intended to be supported by the conduit, and straps should be installed near the appliance.

Good practice as to efficiency, cost and time dictates that all straight leads of conduit should be coupled together by screwing a length into the coupling of the last (each length having one coupling already screwed on when bought); when a wiring appliance is to be inserted a nipple must be screwed into the appliance, a coupling screwed on to this and then the next length of conduit screwed into this conduit. The appliance should be inserted at the end of a conduit length if practicable; if not, the conduit must be cut and threaded. When a bend must occur a union should be inserted in the line and the conduit cut to suit, *but under no circumstances should a "split coupling" be permitted anywhere on a conduit line, or any joint at a bend be made with a right and left handed coupling.*

Conduit and Conduit Fittings.

The types and various sizes are described under Wiring Appliances, and the following are, in general, their uses:

Brass enameled conduit is used wherever a run is to be made within 12 feet of binnacles, unless the compass is fully shielded by a steel deck or bulkhead; and for lengths through decks and bulkheads when exposed to salt water. When a bend is short, or a number of short bends are necessary, brass conduit is often useful by reason of its greater ductility. It is commonly used for truck-light or other circuits on wooden masts.

In all other cases *steel, enameled conduit* is used throughout.

Elbow, 90 degrees, with equal legs, are intended for all ordinary bends required.

Outlet elbows, 90 degrees, are only used in locations where it is absolutely necessary to make a shorter bend than can be done by the elbows, or for bends that cannot be made by the conduit bending machine.

Outlet elbows, 45 degrees, replace the outlet elbows, 90 degrees, in locations where two 45-degree elbows give a better bend than can be obtained by the 90-degree elbows.

Outlet elbows, 90 degrees, unequal legs, and long elbows, 90 degrees, unequal legs, are used similarly to the elbows, 90 degrees, with equal legs, but are better adapted to some locations when shorter radius of bend or length is necessary.

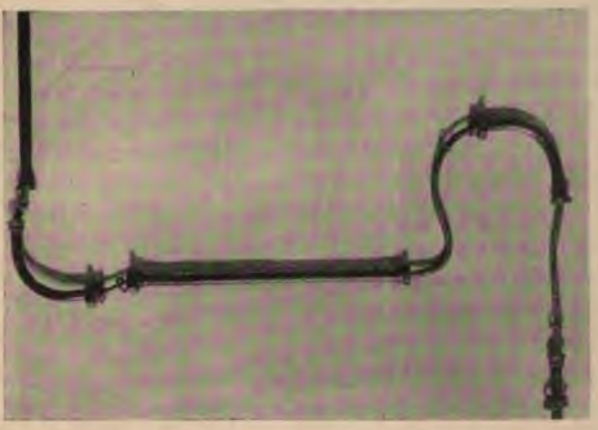


FIG. 294.—Sample of conduit joints using unions.

Nipples.—The right and left are used at each end of every run, excepting when the run is very short; they form a ready means of attachment of fixtures or appliances to the conduit.

Couplings, right-hand, form the regular means of joining the lengths of conduit and nipples.

Couplings, right and left, are used with the right and left hand nipple.

Couplings, reducing, are only used in the special cases when the appliance may be drilled for a smaller size than the local run of the conduit, and, the clearance still being sufficient for the conductor, it is not desirable to enlarge the drilling and tapping of the appliance.

Unions.—Supplementing the use of the pulling box and pull-

ing sleeves, unions *with lips ground off,* are used on the end of all elbows, 90 degrees, unequal legs, outlet elbows, 90 degrees, unequal legs, or special bends to replace them, as shown in Fig. 294. In order that the elbow may be removed from the runs of conduit which they join, and access be had to the conductor when pulling in or out of the conduit, the full benefit of this plan will necessitate drawing wire in straight runs of conduit only, or in those with easy bends.

The unions are made water-tight by a two-ply cloth-insertion sheet-rubber gasket, ⅛-inch thick, and the full width of the surface available in the union. The possibility of water gaining access to the interior of the conduit makes it undesirable to use unions in exposed locations on decks or where they will be exposed to water or drip of any kind.

"**Running threads**" are inadmissible. This type of joint (sometimes confounded with the "split coupling," and as objectionable) has a long thread which is fitted for an extra half-coupling which screws down against the full coupling after assembly, and intended to act as a lock-nut; the space between the full coupling and half-coupling is packed with lamp wick and red lead. Experience demonstrates that the coupling forms a very insecure joint and breaks open when the pipe is under strain, even that of expansion and contraction.

Bushes reduce from one pipe size to the next smaller where the appliance has been drilled and tapped larger than is necessary for the pipe size that is being used.

Pulling sleeves are rarely used except in the long, straight runs of colliers, auxiliaries, etc.; they are intended to afford a separation between ends of conduits, varying from 9 inches in the ½-inch pipe size to 14, 18, 22, 26, and 30 inches in the larger pipe sizes. The gap permits making a bight in the conductor as it is pulled into the conduit, or of inserting the conductor both ways from the gap when pulled in. The leads of the pulling sleeves are water-tighted on the outer surface of the conduit in the same manner as for standard conduit stuffing tubes. It is desirable to securely support the two conduits on either side of the pulling sleeve that there may be no working on the gasket. It is also necessary to lower the conduit below the edges of the beams for a sufficient distance to draw the full length of the pulling sleeve one way or the other on either side of the gap. The pulling sleeve

is intended to be placed in the straight runs of conduit where the length is sufficient to make the pulling in of the conductors difficult; the friction of the wire at bends is obviated by unions.

Laying Out.—While the tentative wiring plans indicate to a great extent the general trend of the conduit leads, variations are made necessary in the finished work by the many necessities for other appliances than the electrical and some considerations which can be mentioned only in a general way.

Wiring appliances in covered locations should be so located that they will not be subjected to drip or leakage from valves or joints or oil.

Deck or bulkhead fixtures may in many cases be attached directly to the auxiliary machinery with better effect than installing drop lights from the deck or bulkheads.

In locating conduits and appliances to decks the upper side of which are covered by wood deck planking, care must be taken to avoid covering over the deck bolts which secure the planking in place; when it is necessary to renew this wood deck planking access to the ends of the bolts from the under side is necessary in order that the holes may be drilled in the wood, and an unobstructed access to them is required. When practicable to span a distance covered by wood deck planking, it is desirable to secure the conduit to the adjacent steel deck plating in order that, when the planking is renewed, it may not be necessary to remove the bolts from the wood.

All conductors above 60,000 cm. have a separate conduit for each leg and the pairs of conduits constituting each circuit should be kept as closely together as possible throughout the entire length of the run; below 60,000 cm. both legs are run in the same conduit, twin wire being used.

Use templates instead of the appliances themselves. The work will ordinarily be facilitated by leaving the drilling and tapping for ordinary appliances until after the appliances are connected to the conduits and thus avoid the necessity for close fit on the length of conduit run.

When locating an appliance which requires a double run of conduit, and near a deck or bulkhead, consideration must be given to the spacings required for the conduits in the appliances and also for the spaces for the stuffing tubes in going through the

deck or bulkhead, in order that special short bends may not be required in a short run of conduit.

Where offsets in a run of conduit may be saved, and head room will permit, the smaller appliances, such as junction boxes, feeder boxes, etc., may be held clear from the bulkheads or decks, being supported only by the run of conduit, this being attached to the beams or stiffeners.

Keep as clear as possible of all spaces required for passages and for the operation of other appliances.

Avoid overhead runs in hot locations in order to prevent deterioration of the insulation of conductors, and runs near heated surfaces, such as boiler casings or the flanges of steam pipes which are run through bulkheads. The runs in bunkers should be so located as to be as free as possible from damage by the dropping of coal. When running near pipes which are to be lagged, ample room for the lagging should be allowed.

Especial care is to be taken in magazines and shell rooms to interfere the least possible with the stowage space required for the ammunition and a run should be selected which will avoid possibility of damage to the conduit in handling heavy ammunition.

Bending, Cutting, and Threading.

Bending of conduit is done by the convenient apparatus shown in Fig. 295, which consists essentially of a 30-ton oil jack fitted with a notched curved toe, and two shoes which can be conveniently and securely set in the base. When in use the apparatus is strapped to a stanchion.

The jack is secured to the upper part of the casting by a cap clamping it into a recess in the main casting. A threaded collar clamps up against the sides of the recess and cap and rigidly secures it in place. The neck of the casting is reinforced by two steel rods T-headed at upper and lower ends and shrunk into place between lugs.

The jack is operated as usual by the lever shown on the left the lever extending to the right being for rapid movements up and down when no power is required.

A bevelled shoe at the bottom of the jack takes the upper forming block which has a groove cast in its curved lower side which is adapted to the outside diameter of the conduit to be bent and

for the minimum standard radius. These blocks are applicable to one size of conduit only and are readily removable for any other size. The lower forming blocks are double on each side.

The lower part is adjustable for distance from the center. The thrust in two directions is taken up by a single longitudinal extension with several in the transverse direction. The upper part is variable for each size of conduit and can rotate on a pivot fitting in a circular recess in the lower part when adjacent bends are required in different planes.

FIG. 295.—Conduit bending machine.

The attention required is that the plunger is kept well lubricated to prevent cutting.

Bending is done to templates of ¼-inch iron rod shaped to the location for the conduit.

Cutting of conduit is done by one of the regular forms of pipe cutter. After cutting, the ends are faced true and square all round before threading, and the inner edges bevelled with the reamer shown in Fig. 296; this guards against abrading the conductors when pulled through the conduit. Reamers are the best for this work, as files do not give a satisfactory result.

Threading of Conduit.—Threads should be of standard diam-

eters, the adjustment of the dies being checked as required; threads should not be cut small by reversing dies.

An excess of oil is to be avoided in cutting and threading and all remaining is to be thoroughly cleaned off, especially inside of the conduit, in order that the painting may be effectual and no oil be present to affect the insulation of the conductor.

FIG. 296.—Conduit reamer.

Painting.

Sabin's air drying enamel is an approved paint for enameled conduit.

All conduit, excepting in quarters, should receive after instal-lation not less than two good coats in order to thoroughly protect the surface from corrosion. This is especially important in fire-rooms, up-takes, bunkers, engine rooms, shaft alleys, upper decks, masts, conning-tower tube, and galleys. In quarters and other locations where not especially exposed it will be sufficient if the conduit receives the regular white oil paint.

The directions for the use of the enamel are:

Do not use any thinner.

In cold locations it may be warmed to make it more fluid.

It will usually require 36 hours to dry sufficiently to handle. In hot dry weather it may dry in 12 hours. If dried by heat (200 degrees to 250 degrees F.) it will dry in about two hours.

A second coat should not be applied in less than three days; and 10 days is better.

The success of the application of the enamel will always depend on the cleanliness of the surfaces and their freedom from grease and oil.

Templates.

The templates for fitting the bends required in the conduits are ¼-inch diameter, round, iron rod, those for fitting special straps 1 inch by 14 B. & S. G. band iron.

Elbows and Bends.

Insulating outlet elbows are to be used only where no other method will answer.

Use elbows as often as possible instead of making bends in long lengths in order that there shall be less reduction in area and that unions may be used at their ends.

All bends are made in the hydraulic form of benders; bending by heat usually flattens the pipe and can be tolerated only for small or twin wire.

There must be no detrimental flattening on any bend. A bend in which the area is materially reduced must not be used.

When heated bends are made for special locations they must be thoroughly enameled inside and out.

Water-tighting.

Conduit is to be continuous and without open joints. Where required to be water-tight at bulkheads and decks the standard stuffing tubes or jamnuts are used; the latter to be used only when the standard stuffing tubes cannot be installed.

When leading from a water-tight compartment to a non-water-tight compartment, or the reverse, or from a water-tight compartment to a compartment in which there is an outlet, and through all decks, the conduit is to be water-tighted inside each water-tight compartment by the use of water-tight boxes, however short the run or despite the fact that the conduit may be only led

through the compartment in going from one to another; this rule should be inflexible as otherwise the intent of water-tighting (which is to protect a water-tight compartment from the inflow of water from any other compartment) is not efficiently carried out.

In going through decks and bulkheads the circuit is made water-tight around the conduit by standard stuffing tubes.

If the conduit starts and ends in the same compartment, being used for mechanical protection only, water-tighting is not ordinarily required at either end; the possibility of chafing the conductor on the edge of the conduit at the ends is prevented by the use of an outlet insulator.

Clearance.

The clearance determines the pipe size of conduit for use with the size of the conductor. A clearance of from 5/32 to 3/16 of an inch is to be allowed for drawing circular conductors in and out; for oval sectioned conductors this may be reduced to from 3/32 to ⅛ of an inch.

Caution.—The apprehension in pulling (or drawing) conductors is that the rubber insulation on the wire will be broken and fractured, it is particularly a menace in conductors which have been manufactured six months or more. As the copper is very ductile, the rubber insulation liable to fracture, and the braid to stretch, rupturing the insulation is comparatively easy under the large stress which is necessary to draw a large wire, say, of 200,000 cm. and above; hence a safe clearance allowance is mandatory, and this is especially to be looked out for in bends.

Inspecton.

Before putting up any length of conduit fitting look through each length of conduit and each fitting to see that the bore is smooth, of full diameter and of circular section.

It must be seen that the inner edges at the ends have been properly bevelled or rounded, and that a full, strong thread has been cut; the fusing of a bend on board an armored cruiser, causing fire in a magazine, has been caused by neglect of this injunction, the insulation of the wire having been stripped by the cutting edge of an elbow in drawing.

Insulators.

An incidental advantage of the use of this method which is of pecial value in crowded locations, such as dynamo-rooms, is in e short bends which can be made in the conductor as compared ith conduit work.

The following table is useful as a guide in laying out work, id indicates the minimum safe, inner surface, radius of bends hich can be used without detrimental stress on the rubber insution or protecting braid:

Wire for Lighting, Motor, Etc., Circuits.

Single.		Radius.
4,000	cm.	2 inches.
9,000	"	3 "
11,000	"	3 "
15,000	"	3 "
18,000	"	3 "
20,000	"	3 "
30,000	"	3 "
40,000	"	4 "
50,000	"	4 "
60,000	"	4 "
80,000	"	5 "
100,000	"	5 "
125,000	"	5 "
150,000	"	6 "
200,000	"	6 "
250,000	"	6 "
300,000	"	7 "
375,000	"	7 "
400,000	"	7 "
500,000	"	8 "
650,000	"	9 "
800,000	"	10 "
1,000,000	"	12 "

Twin.		Radius.
4,000	cm.	2 inches.
9,000	"	3 "
11,000	"	3 "
15,000	"	3 "
18,000	"	4 "
20,000	"	4 "
30,000	"	4 "
40,000	"	5 "
50,000	"	6 "
60,000	"	7 "

Inter-Communication Cable.

		Radius.
2	Conductor	3 inches.
3	"	3 "
4	"	4 "
5	"	4 "
6	"	4 "
7	"	4 "
8	"	4 "
9	"	5 "
10	"	5 "
11	"	5 "
12	"	5 "
13	"	5 "
14	"	5 "
15	"	6 "
16	"	6 "
17	"	6 "
18	"	7 "
19	"	7 "
20	"	7 "

The types of insulators have already been described. There is a new variety for use with sheet metal hangers consisting of a flanged bush, one part screwing into the other and thus adjustable after the hanger has been put in place.

Molding.

The backing strip, laid in advance, is secured by brass machine screws (No. 14-20), placed alternately on the sides, and so spaced (about 12 inches apart) that no screws will come under junction boxes, switches, or receptacles; the screw heads being countersunk.

Molding is secured in place through the center wall with brass wood screws (No. 8, 1½ inches). Screws are placed, as directed, at intervals not greater than 12 inches; the screw heads being countersunk to make a fair surface for the capping.

Molding is finished in the same manner as the surrounding woodwork, and all molding and backing except hard wood is thoroughly coated with white lead paint after being fitted and before being secured in place. All molding is capped, *the capping being secured to the side walls* by roundhead brass screws placed not more than 12 inches apart.

In running the backing strip a path that will clear usual sized

boltheads and other projections is chosen. To avoid such obstacles, small detours from a direct lead are allowed.

The part of the molding under the wire gutters is never reduced in thickness below 3/8 inch.

Junction boxes, switches, and receptacles (combined or separated) are separated from metal surfaces by at least 3/4 of an inch of wood, and secured with brass wood screws entering the wood for 1/2 inch. It is required that at least 1/4 inch of clear solid wood shall separate all wiring accessories from the metal of the vessel.

The junction boxes, switches, and receptacles being wider than the backing strip, the latter are always built out to bring it flush with their sides, except where a number of moldings are grouped together, as in passageways where feeders are run; then these boxs can be let into adjacent moldings (never more than 3/16 inch) and so disposed that no two in adjacent moldings will be abreast. They are never located over screws which secure the backing in place.

Controlling switches, feeder junction boxes, and distribution boxes are placed with especial reference to convenience of access.

Where several leads of molding run side by side, a backing strip of the required thickness in one width may be used under all.

When the run changes from molding to conduit or the reverse, the end of the conduit is fitted with a standard conduit terminal tube. The backing strip of the molding extends under the terminal tube, and the molding part cut off square about 3 inches away from the end of the assembled gland. The capping extends beyond the end of molding and butts up against the gland. Two side pieces are fitted from the end of the molding proper to the terminal tube, thus forming a sort of box to give room for access to the gland and gasket of the terminal tube.

Neither twin-conductor lighting wire, nor any other double conductor or cable which would be liable to cause dangerous short circuits by being damaged, are installed in molding.

Electrical Interior-Communications.

The installation of conduit and molding for interior-communication is in accordance with that described for lighting.

Wiring.

All wire, whether for use on dynamo current or battery is that prescribed by the specifications for bell wire and interior-communication cable; the specified bell wire and interior-communication cable is used on all circuits, whether for call bells, telegraphs, or indicators, excepting where a standard special cable has been specified for a particular use.

Interior-communication cable is used for all circuits below the main deck; bell wire may be used in quarters and for offices the governing principle to be to secure thorough water-tightness between the water-tight and non-water-tight sections of the vessel, which will necessitate in some cases the extension of the cable into the non-water-tight sections through the water-tight bulkhead. Not more than 40 wires are used in any one lead. Interior-communication cable is also used for circuits to the conning tower, chart house, military top, signal towers, emergency cabins, and bridge.

When using interior-communication cable, the number of spare wires in each cable is not to be less than one for cables up to nine conductors; not less than two for cables up to 21 conductors, and not less than three for cables up to 40 conductors.

Ten-wire, 20-wire, and 40-wire connection boxes are used as may be most suitable for the particular case, special reference being had to reducing the number of boxes to a convenient minimum.

All wires or cables are run where directed and where accessible, those for circuits used in action being kept below the water-line as much as possible.

Action Cut-out Switches.—Circuits used in action which are protected, and which are connected to exposed circuits, are provided with action cut-out switches for cutting out the exposed portions of the circuits.

The use of action cut-out switches is limited to such switches of interior-communication as are used in battle *and does not include the following (except as noted in case 3)*:

Voice tube calls.
Telephone calls.
Quarters and office calls.
Boat hour gongs.
Alarm gong circuits.
Fire alarms.
Warning signal circuits.

The following are always provided with this type of switch:

Shaft indicator circuits.	Steering telegraphs.
Engine revolution telegraphs.	Helm angle indicators.
Battery control.	Power door indicator circuits.

Their use on these circuits is determined as follows:

Case 1. More Than One Transmitter on a System.

If one or more transmitters are located behind armor and one or more transmitters are not behind armor, circuits to those not behind armor are fitted with cut-out switches.

If none of the transmitters are behind armor no cut-out switches are installed on the circuits to the transmitters.

If all of the transmitters are behind armor no cut-out switches are installed on the circuits to the transmitters.

If one, any or all, transmitters are located behind armor and some indicators are not behind armor, cut-out switches are installed on the circuits to such indicators.

If none of the indicators are behind armor no cut-out switches are installed on the circuits to the indicators.

If all the indicators are behind armor no cut-out switches are installed on the circuits to the indicators.

Case 2. Only One Transmitter on a System.

If some indicators are behind armor and other indicators are not behind armor, cut-out switches are installed on the circuits to such indicators as are not behind armor.

If none of the indicators are behind armor no cut-out switches are installed.

If all of the indicators are behind armor, no cut-out switches are installed.

Case 3. When voice tube calls, telephone calls, general alarm wiring and warning signal wiring extend from outlets in conning tower up to pilot house or bridge, cut-out switches are fitted on all such circuits before they leave the conning tower.

General Directions as to Wiring.

The outer braid and tape on the ends of all bell wire and cable, where they are connected through gaskets in boxes, cut-outs or instruments, is not removed, as was the older practice.

All wire and cable run through decks or bulkheads, when molding is used, are led through standard stuffing tubes. When run-

ning through beams or bulkheads, and water-tightness is not required, the hole for the lead is bushed with hard rubber when molding or insulators are used.

No circuits are led overhead in locations subject to heat, or through or into coal bunkers, unless specifically necessary.

All conductors are run in conduit; insulator and molding work being specially authorized and approved.

Soldering Joints and Wire Ends.

The number of soldered joints in single conductor circuits must be entirely avoided if practicable. When soldered joints are made it is done by first cleaning the wires, then twisting closely together and heating only sufficiently to cause the solder to flow freely into the joint. The heating is preferably done with a soldering iron. If a soldering lamp is used special precaution is taken to prevent overheating of the rubber. The solder for making joints is of the rosin core type; no flux other than rosin is used. All joints are taped while warm with a layer of rubber tape, and covered with an outside layer of cotton tape for protection against mechanical injury.

In making joints between bell wires and interior-communication cables, the interior-communication cable is run through the water-tight deck or bulkhead into the location where the bell wires terminate and the junction there made in standard connection boxes.

Soldering the ends of conductors in order to fix the single wires of the strands when they are to be inserted under binding caps is bad practice and is not admissible; the fringed wires make better contact and hold more securely than the soldered end. Soldered ends frequently slip out from beneath the cap. A "soldered end," however, is not to be construed to apply to soldering the ends of wires into connectors (Fig. 90, *A*).

Fishing.—All short lengths which can readily be handled by one man are fished with the usual steel snakes.

In long lengths the first line through is led from the device, to be connected with the compressed air nozzle, shown in Fig. 297; the air pressure being supplied in ships so fitted, from the air pressure lines used for the drills, chippers and riveters. In ships not so fitted a hand operated air pump is used. After the fish line is blown through a hemp line is attached to supply the strength required to draw the conductor.

In operating, the soft leather bucket is pushed into the conduit, the nozzle is inserted into the end of the conduit, and the cock then opened. The device, on test, drove the bucket through 350 feet of conduit and past four bends in three seconds; the soft leather bucket is more efficient than a ball or other arrangement.

FIG. 297.—Device for blowing a reeving line through a line of conduit.

FIG. 298.—Cable grip.

The line used is small fishing line which, after being driven through, is used to haul larger line, rope, etc., through.

Cable Grips.—For drawing cables and conductors in conduits the connection between the conductor and the rope is made by the cable grip as shown in Fig. 298. The grip is made in the following sizes:

1¾	inches	to	⅞	inch.
1½	"	"	¾	"
1	"	"	⅝	"
¾	"	"	⅜	"

The tension on the grip causes it to close in and bind the outside of the conductor so tightly that any necessary tension for pulling the conductor through the conduit will not cause it to loosen and slip.

Lubrication in Pulling Conductors.

Soapstone powder is to be blown by a bellows or by the compressed air fish device before entering the conductor. It is also always to be rubbed into the outside braid of the conductor to facilitate drawing in; and especially for the purpose of preventing the conductor from sticking in heated locations, causing extra stress in drawing and withdrawal.

The utmost care is to be taken to prevent the powder from getting on any parts of adjacent machinery which it can damage, especially their journals and lubricators.

Inspection After Completion of Work.

After the conductors have been placed and connected the integrity of the conduit work must be inspected at all its joints in couplings and unions.

The unions must be slacked back, and the use of the gasket and its having even contact definitely determined.

The tightness of all covers of all boxes is examined and the condition of all gaskets in pulling sleeves, deck, and bukhead stuffing tubes.

The condition of the painting in all locations especially requiring enamel is looked into when going over the points previously mentioned.

Jointing Up and Securing.—All joints must be screwed up tight, as for steam or water under pressure.

A right and left coupling must have an even number of threads in the conduit in each end.

In entering appliances it is necessary that the end of the conduit shall come flush with the inside in order that the conductors may not be abraded by the sharp edges of the thread before being protected by the bevelled inner edge of the conduit or nipple.

Circuits are led through armor by drilling a clearance hole and inserting a long nipple, the conduit being connected by a coupling or a union on each end; water-tightness is secured by jamnuts screwing along the nipple tight against the armor, one nut on each side.

During installation the ends of conduits on exposed locations must be closed by wooden plugs or oakum to prevent access of rain and damp air to the interior of the conduit; to the same end box and instrument covers should be installed with the least practicable delay.

Gaskets.

When gaskets are used for water-tighting around the outside of the conduit, the conduit may first be installed without the gasket, and then each gasket as installed may be cut along the line parallel with the axis of the hole; the gasket can then be forced open and slipped around the conduit. Care must be taken that the gasket is closely joined together when set up and thoroughly seals the cut. The location of the cut on inserting the gasket must be such that it can be readily inspected when the gland is being set up.

The packing of covers of boxes should be rubbed with chalk or soapstone to ensure that they will not stick to the edge of the box and prevent the ready removal of the cover.

Particular Hints and Some Faults Occurring from Errors of Management.

The Turret Base.

This term refers to a casting, about 12 inches in diameter, through which are led the circuits for the turret. Its object is to centralize these circuits to minimize the twist when the turret is revolved; the number of circuits may be as great as 17 and these must be massed as closely as practicable around the center spindle or air-pipe.

The casting usually consists of two ½-inch composition plates between which is compressed a circular gasket of soft rubber, ½ inch thick, the rubber binding against the circuit wires to hold them tightly in the base and prevent any twist within the water-tight box beneath the handling room (and located as a rule over the center line bulkhead between two magazines).

Four methods of construction of this base casting are in use: *One*, in which the casting is bored larger than the diameter of the wire, the soft rubber being bored for a neat fit around the wire and in this case only the compression of the top plate can be relied on to water-tight the wire and grip it against the probable twist

in the box below (which would endanger chafing off the insulation as has occurred) ; *a second,* is to bore the casting and rubber as in the last case, but in addition to bush the bores of the castings with hard rubber, this is an improvement on the first plan, but still insufficient to prevent twist; *a third,* provides more compression of the soft rubber against the twisting effect by soldering rings to the cap and bottom plates at each bore and cutting channels in the soft rubber, a method that proves to secure better rigidity; in the *fourth and latest* method, the entire construction is changed and the wires held securely in separate stuffing tubes screwed and soldered in a single plate casting, a ¼-inch gasket is assembled with the plate for water-tighting.

Distributing Twist Above the Turret Base Casting.—As the turret circuits are of unequal wire size, the effect of the twist when the turret is revolving is different for each wire size causing chafing not only of the wires on the central pipe, but on themselves. This is best obviated by using sleeves cut from brass tubing, giving a clearance of ¼ inch on the wire and about 10 to 12 inches in length. These are slipped over the air-pipe and spaced equally in the height from the turret base up. From six to eight sleeves will suffice for a 12-inch turret and four to five for an 8-inch turret. The wires are brought in and seized to the sleeves with steel wire seizings, the sleeves being preferably drilled for the purpose. The method will evidently prevent any chafing and adds much to the neatness of the assemblage.

Circuits Inside of Magazines.

Present rules require that when a circuit which is to be fed at dynamo potential is led through or into a magazine or shell room the conduit shall be protected by a covering ¼ inch thick (10-pound plate). No circuits should therefore be led into or through these compartments, and thus involve the extra weight, if it can possibly be avoided; the one actual necessity is for the circuits leading to the water-tight box under the turret base casting.

For lower potential circuits, such as those for thermostats, no covering is required; but for the general case of the thermostat, its location at the side rather than the upper center of the magazine or shell room is sufficient for its intended use.

Running Conduit Through Beams.

This practice is so general, although against all rule, that it is again emphasized as to be prohibited.

Voice Tube from the Starboard Bow to the Bridge.

This very convenient voice pipe is commonly omitted. Its installation is quite important as conducing to quiet when working anchors and chains.

Taffrail Lights.

The installation of outlets for the stern light, peak light, propeller boom lights and for deck lights about the taffrail is much simplified by a device consisting of 1¼-inch conduit with two T branches, on which can be installed five switch-and-receptacles. The conduit is led up from below and goose-necked to turn down with the flag staff out of the way of the guns. The device is contained in a standard drawing.

Securing Lights Under Beams.

This practice of securing fixtures under the lower flange of channel beams invariably results in insufficient head room under the globe and should be prohibited, except in certain cases inside of quarters, even then there exists no real necessity and an avoidance of the practice altogether is advisable. The rule for securing fixtures is to secure them in almost every case to the deck above to the entire exclusion of locations against a beam, and if the resulting dispersion appears then to be insufficient the proper practice is to install more fixtures.

Circuits in Hot Locations.

The chief of such hot locations are the upper parts of fire-rooms. In general no circuit should be led into or through any fire-room if it can be at all avoided; the main circuits and especially interior-communication circuits should be located in the passages; in the repair of former installations where circuits had been led through fire-rooms from apparent necessity a new lead in the passage has been found without difficulty, and no exception is known.

Cases of melting off the insulation from wiring are common when subjected to fire-room temperatures.

Helm Angle Indicator.

An indicative cause of faults can be instanced in the frequent faults in this instrument; in all cases the fault has been due to condensation within the contact box or to dropping short-circuiting matter into the box when cleaning it out.

Appliances on the bridge frequently fail from this corrosion from condensation or from not keeping the cover packed; it is also a usual cause of failure of telephones—salt water and air is the chief occasion.

Wiring Appliances.

No appliance should ever be covered until cleared of all foreign matter, such as filings or copper dust from the wire ends after cleaning and brightening before securing under the contacts.

Tests After Installation.

The acceptance tests of the material apply to the original supply only; subsequent inspection of the generating sets, wiring appliances, fixtures, apparatus, and instruments is to assure their efficiency and construction after shipment, and after placing in the assigned location in the ship; but the object of the test is to assure that the installed material is in condition for commissioning the vessel and hence in contract work the original acceptance tests are provisional only, and the material accepted preliminarily and to be subjected to the final tests for final acceptance; to this end the tests should not be made until within a short time of the vessel's delivery, and not greater than two months previously.

So many items intervene that it is not practicable to formulate any exact chronology of the tests required, but they can be outlined for the general case by referring them to the 48-hour service test which is in reality especially intended as a test of the generating sets and during which there is not sufficient time to undertake a careful test in other regards. In the following outline the time required is about ten days.

Test of Insulation Resistance, Cold.

When measuring the ohmic insulation resistance of lighting circuits 125 volts is now used for the potential, but 500 volts is preferable if available. Hereafter the lighting circuits are to be

tested by alternating current; all lighting circuits having metal sockets in line are tested at 500 volts A. C., and all other lighting circuits at 750 volts A. C., the tests to be made in dry weather after an inspection of the appliances and accessories to see that they are free from moisture and dust. The current is supplied from an oil insulated static transformer which is ordinarily supplied with current from the alternating current dynamo of the motor generator for wireless telegraph installed in the vessel. The output of the transformer is rated at 600 watts and with a range of secondary voltage of 250, 500, 750, 1000, 1250, and 1500 by taps from the secondary winding. The primary is adapted for 110 volts, 60 cycles. Of the taps the 250, 500, and 750 only are run out and made selective by a switch. An alternating voltmeter of scale to over 750 volts is supplied to be put across the secondary terminals of the transformer.

Caution.—Great care must be exercised in handling these high voltage currents as the peak of the wave is 40 per cent higher than the values stated, which are mean, *making each one including the lowest dangerous to life.* When the circuits are being tested special precautions should also be taken to prevent all other persons from handling them in any way.

The insulation resistance of motor circuits is usually tested at a potential of 500 volts, if available, otherwise 125 volts is employed.

While it is common practice to test the insulation of interior-communication circuits at 125 volts, 500 volts is better in its results and gives more accurate indications of the actual; this has been the invariable practice at the New York Navy Yard. In fact all insulation resistance, other than by alternating current, has been tested at that navy yard at 500 volts using the ohmmeter as a material time-saving device. The Evershed type is that in use and is an adaptation of the two-coil ohmmeter with a portable hand dynamo yielding a continuous current. The electrical principle is indicated in Fig. 299. The current from the dynamo *D* divides at the ohmmeter into two parts, of which one flows through the pressure coil *P*, and constant resistance *R*, and tends to turn the magnetized needle and index hand towards the infinity point on the scale, while the other fraction of the current traverses the windings of the current coil *M* and the leakage path *X* through the insulation which is under test.

When there is no leakage the current coil has no force and the

needle is free to lie in the magnetic axis of the pressure coil; the index then stands at the last division of the scale, which is accordingly marked "infinity." If the insulation resistance is so low as to be negligible, the current flowing through the current coil will depend only on the volts and the resistance of the current coil itself. The current coil will now deflect the needle away from "infinity" to a position in which the turning moments of the two coils are balances.

This point on the scale is marked "zero." Obviously, for any

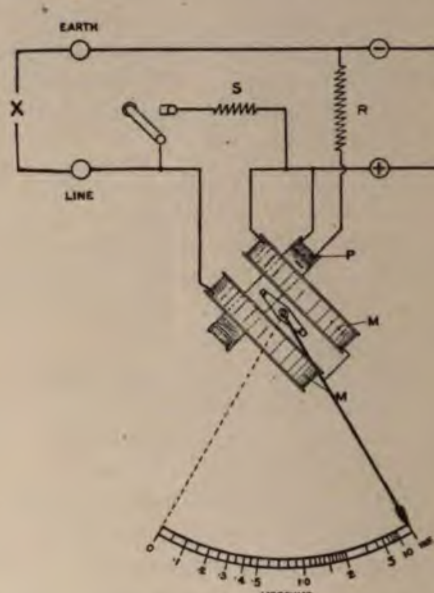


FIG. 299.—Diagram of circuits of the Evershed ohmmeter.

given resistance in the leakage path the index will come to rest at a definite point between zero and infinity. Moreover, if the resistance is constant and independent of the voltage, the position of the index will not be changed by increasing or decreasing the volts, for if the volts are doubled, for example, the currents in both coils will be doubled and their ratio remains unchanged. Hence the angular position of the needle and index indicate resistance quite apart from voltage.

This instrument directly indicates the value of the resistance

under test by means of a pointer which ranges over a scale of ohms and megohms, just as an amperemeter indicates amperes or a voltmeter, volts.

In the latest pattern of Evershed testing set, the hand dynamo has a tunnel wound armature, a finely laminated core built from stampings of best iron, a special form of commutator with elastic roller brushes and roller bearings for the armature axle. It is driven by double gearing. The winch handle is hinged so that it may be turned down into a recess in the box when not in use. A convenient flexible connector is provided for coupling the dynamo to the ohmmeter. The ohmmeter has a very finely pivoted astatic needle system, magnetized by the dynamo current, and, therefore, free from all the troubles incidental to permanently magnetized astatic needles. The needle system is automatically lifted off the jewel bearing and securely clamped by the action of shutting the lid of the box. The current coil is wound with a large number of turns of fine wire to secure the maximum sensibility. A one-ninth shunt is provided to reduce the sensibility ten times when low insulation resistances are being tested. There are four terminals on the ohmmeter; two of these serve for the connections to the dynamo, and the other two are marked "line" and "earth," respectively, and to these the circuit which is to be tested must be connected.

There is no adjustment of any kind to be made beyond turning two leveling screws on the ohmmeter until the bubble of a circular spirit level stands central. The scale reads in megohms.

It is essential in operating an ohmmeter that it be level and removed from the vicinity of iron; neglect of these precautions produce very erroneous readings.

A good preparation for the final insulation test is to ring through each line of wiring with a magneto as the wiring is installed; this instrument having a resistance of 50,000 ohms that much insulation of each leg of the circuit to ground is thereby assured. Failures of insulation resistance are in many cases to be located in a badly placed fuse in a feeder or branch box, emphasizing the necessity of the inspection of all wiring appliances and connections before the insulation test is made; if the fault is not to be located in these connections an elimination from box to box and circuit to circuit is necessary.

When making the cold insulation resistance test all lamps are left in their sockets with switches turned off, and all portables are unplugged; all motor circuits are to be cut out at the switchboard, but are tested separately as far as the main switch connecting to the panel or rheostat.

The 48-Hour Service Test.

This is a test of endurance of the generating sets and the incidentals thereto, each generating set being required to run on some load between full load and no load, and for two hours on one-third overload, for a continuous period of 48 hours.

Ordinarily but two sets are run at the same time owing to the congested space in ships' dynamo-rooms, the number of people required, and the lack of necessary space for instruments and recording data; and incidentally the fact that night work and overtime is required, it being necessary to reduce the last to a minimum.

For the load, all that is available in the ship should be first connected in; for a battleship this will be about 1200 amperes, the searchlights not being considered as they cannot be safely run for more than two hours at a time, and, excepting in the case of the one-third overload, should not be used for the purpose of the test at all; there will, therefore, be required to be prepared beforehand—in view of the paralleling test—at least 1200 amperes in water rheostats for generating sets of 100-k. w. capacity, to give the necessary load of 2400 amperes for the total test.

Two sets may be started about four hours apart, though an interval of six hours is better; if three machines are to run a less interval than eight hours apart will be found to be very inconvenient for recording.

Before Starting the Test.

1. Prepare the log sheets. These should contain all the data of the test with a large column for remarks to include all incidents; especially are to be recorded the fact of testing the valve settings, brush positions, compounding, etc., which are often adjusted before the service test is made and not examined into in time to avoid loss of time when required to shut down; the adjustment of the valves and brush settings and compounding should be ascer-

tained as soon as the set is steady on the load that there may not be one position of the brush for the paralleling and another for the heat run.

The log sheet should be comprehensive of all details of the machine itself and every minute of the test.

2. Have all gages and instruments calibrated. As in acceptance the accuracy of the gages and instruments is most conveniently expressed as a factor.

3. Provide thermometers for the heating tests; the thermometers should read in divisions of one degree between zero degrees and one hundred degrees centigrade, and should be about six inches long, the mercury bulb to have a diameter of about 3/16 inch, and not greater than the diameter of the stem.

4. Provide water rheostats for all load for paralleling three machines, about 1200 amperes for 100-k. w. generators.

5. At some time within about three days of running the test take a characteristic of each generator, in five steps, from full load to no load and back to check the brush positions in conformity with the specification that the characteristic must not vary more than 2½ from the rated voltage of the generator at any point of the curve. It has been found that the compounding of generators is changed during shipment, and after the preliminary acceptance test, and since the series shunt has been permanently adjusted it becomes necessary to readjust the compounding for the new conditions by shifting the position of the brushes, that is the rocker; this should then be marked by a file or chisel, and the position maintained for both the heat run and paralleling.

6. Provide and examine the oil; this oil to be that as generally used in ship work, and as prescribed in the tests of generating sets.

7. Measure the cold temperatures of all the locations as prescribed in acceptance tests, except that of the field, by thermometer. Measuring the heat rise of the armature and series windings by the method of electrical resistance is too delicate a test for tests on shipboard; and the method should not be attempted.

The Service Run.

The data are taken every half-hour and include volts, amperes, R. P. M., steam, vacuum, temperature of air, temperature of field,

and remarks; at random on the sheet are notes of the other requisites, but incidentals of test during the run are entered opposite their proper hour in order that the time and fact may be fixed, being thus complete and accurate for future reference, the *desideratum* being that the test shall be complete and separate in itself.

1. Start the set and adjust all running conditions for operation under full load and when steadily in operation under full load take a good card for examination of the valve settings; if satisfactory, note from the card the steam pressure at the throttle and adjust the reducer for the drop in pressure from the gage tap to the throttle.

Next take a characteristic in five steps from full load down to no load and back to check the compounding and brush position.

Run the set on full load for two hours to warm up the windings before taking the efficiency cards.

2. At the expiration of two hours take a set of cards at ¼ load, ½ load, ¾ load and full load; examine each for the accuracy of the valve settings and file the cards for calculation of efficiency for each stage of load. No-load cards are of negligible utility. If the valve settings are unsatisfactory the set is shut down and a complete new run made.

3. As soon as the verifications of 2 are made adjust the load to one-third overload and run for two hours, taking a good card during the interval for efficiency calculations.

(The valve settings having been examined and the overload run made, there will not be further chance of having to shut down and loss of time will be avoided.)

4. Adjust the load to ¾ load and run until the expiration of the 18th hour.

5. At the end of the 18th hour adjust the load to ½ load and run on that load for 12 hours.

During this period opportunity is usually afforded to test the action of the set under varying steam pressure for vacuum and atmospheric exhaust; the tests required are:

a. Operating on full load, to run at a steam pressure 20 per cent below the normal and on vacuum exhaust.

b. Operating on 90 per cent of full load, to run at a steam pressure 20 per cent below normal and on atmospheric exhaust.

c. Operating on full load, steam pressure 20 per cent above normal, atmospheric exhaust.

d. Operating on full load, steam pressure 20 per cent above normal, vacuum exhaust.

The run should be made for 30 minutes under each condition, and during the time the regulation of the engine for the condition is tested by breaking from the operating load to no load and back three times, noting the initial, final and steady speed and voltage each time, the average being taken as the result for each condition. (It has been customary to take the engine regulation when operating at one-third overload; the practice is likely to occasion serious accident to the engine and should not be tried.)

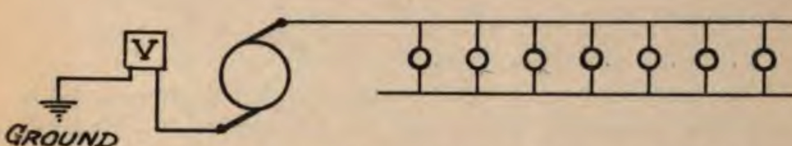


FIG. 300.—Illustrating method of test through circuits under load for insulation resistance.

6. Next adjust the load to ¼ load and run for 12 hours.

During this run opportunity will afford to test the insulation resistance of all the circuits whilst hot. All lights and portables which that circuit is designed to carry are turned off, and the insulation resistance of each leg of each circuit is then measured to ground in the same manner as in taking the cold resistances, and by voltmeter, the ohmic resistance only being measured.

7. The last six hours of the run is required to be made under full load.

Shortly after the set is running steadily test the engine regulation by breaking the load from full load to zero and back in three cycles noting the steady, final and initial voltage and speed; hunting and racing are to be particularly noted.

At some convenient time during the earlier stages of the run take a careful characteristic in five steps, beginning at full load and stepping to no load and back, and then a second curve beginning at no load.

At a later stage test the insulation resistance of all the circuits whilst under load, all lights being turned on and all portables

being connected; the diagrammatic arrangement is shown in Fig. 300.

Towards the end of the run make ready for taking all temperatures and just before shutting down get accurate readings of the voltage across the shunt field (shunt rheostat not included) and the field current.

8. As soon as the set is shut down measure the final temperatures by thermometer of: Armature, bearings, pole tips both entering and trailing, series field, field rheostat, binding wire, commutator, correcting for the temperature of the air and referring to the temperatures when cold for the heat rise during the run.

Next measure the insulation resistance of the generator windings.

Operation in Parallel.

The paralleling test should be made with hot conditions, and if opportunity is not afforded after the service run the machines are to be run until warmed up before making the test.

One machine should first receive an overload and the second then paralleled in, noting the voltages of each machine and its division of load after the operation. Next adjust the voltages of each machine until the division of load is equal, the difference in voltage of the machines for this operation will evidently determine whether the equalizer resistances are properly proportioned; if not, there will always be an unequal division of load between the two machines when at the same voltage and the equalizer resistance should be rectified. This test should be made separately for each machine, paralleling successively with the first.

Having again overloaded the first machine, throw in the second, adjust equal voltage on each and a little lower than the normal and then throw in the third, finally adding load to bring all three up to full load.

Circuit Breakers.

The reliability of all circuit breakers should be tested by subjecting them to overload and checking their sensibility; the required overload not being obtainable, the test is made by slowly reducing the setting by the gage and noting the current as shown by gage when the breaker trips; it is advisable to check the gage at two or more other points. Sufficient current for testing large

capacity breakers is rarely obtainable, and shop tests are therefore accepted.

Searchlights.

These are run for two hours, and the rise in temperature of the windings, barrel, and mirror measured by thermometer.

Motors.

The final test of motors on actual drive is a completion of the general test and as in generators temperatures are taken by thermometer and all apparatus in connection with their operation tested out fully under its service use.

Notes on Final Tests.

The shunt field resistance is measured as the test progresses by taking readings of the current and voltage, this includes the resistance of the rheostat. The cold resistance is taken as that of immediately after starting, but it must be taken almost immediately thereafter, as the field warms up quickly, expedition is therefore necessary; the cold resistance may be measured before starting by the drop of potential method, and this is generally to be preferred.

In taking the temperature of a heated armature the maximum reading is obtained shortly after shutting down, in about one minute; the bulbs of the thermometers are inserted in the armature openings, such as ventilating openings on the back head, in ventilators of the core and on the binding wires.

In reading temperatures record each rise as it occurs and until the readings show a decided decrease, this will assure the maximum.

When sets of different sizes are to be tested in parallel, extra precaution should be taken as to the exactness of the equalizer resistances or the smaller machine may be easily overloaded to the point of danger; the practice is a delicate one at best.

Tests of generators and all apparatus of a ship building at the works of private yards are under the control and direction of the owners and at their risk, inspectors should, therefore, merely indicate the requirements and observe the test; interference in other respects occasions claims for damage and delay.

A service test that should be made during paralleling is the breaking of the whole load whilst two machines are operating on full load, and then throwing in the original load on the two machines; it is taking risk to perform the experiment with three machines under like conditions, although more nearly simulating what might occur in action.